US009592586B2

(12) **United States Patent**
Lehnig et al.

(10) **Patent No.: US 9,592,586 B2**
(45) **Date of Patent: Mar. 14, 2017**

(54) **APPARATUS AND METHOD FOR HIGH FLOW PARTICLE BLASTING WITHOUT PARTICLE STORAGE**

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(73) Assignee: **Cold Jet LLC**, Loveland, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 204 days.

(21) Appl. No.: **13/757,133**

(22) Filed: **Feb. 1, 2013**

(65) **Prior Publication Data**

US 2013/0203325 A1 Aug. 8, 2013

Related U.S. Application Data

(60) Provisional application No. 61/608,639, filed on Mar. 8, 2012, provisional application No. 61/594,347, filed on Feb. 2, 2012.

(51) **Int. Cl.**
B24C 5/06 (2006.01)
B24C 1/00 (2006.01)
B24C 9/00 (2006.01)

(52) **U.S. Cl.**
CPC ***B24C 1/003*** (2013.01); ***B24C 5/06*** (2013.01); ***B24C 9/00*** (2013.01)

(58) **Field of Classification Search**
CPC ... F25C 5/12; B24C 1/003; B24C 9/00; B24C 5/06
See application file for complete search history.

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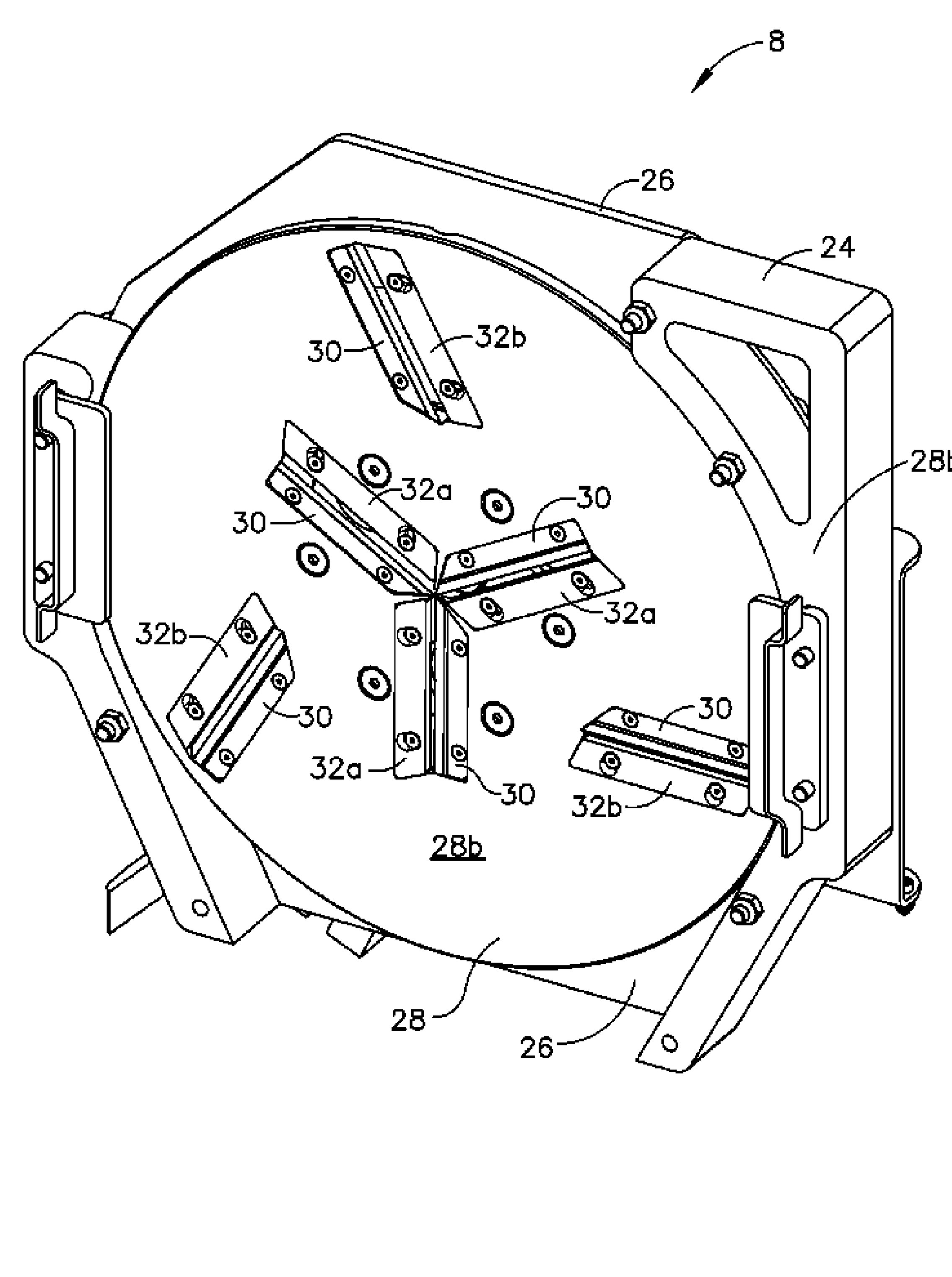
Primary Examiner — Cassey D Bauer
(74) *Attorney, Agent, or Firm* — Frost Brown Todd LLC

(57) **ABSTRACT**

A particle blast apparatus transport is capable of generating granular sized particles and delivering them without substantial storage to a single hose feeder assembly. The apparatus is configured to be used with solid blocks of cryogenic material, such as carbon dioxide, and with individual pellets of such material.

7 Claims, 41 Drawing Sheets



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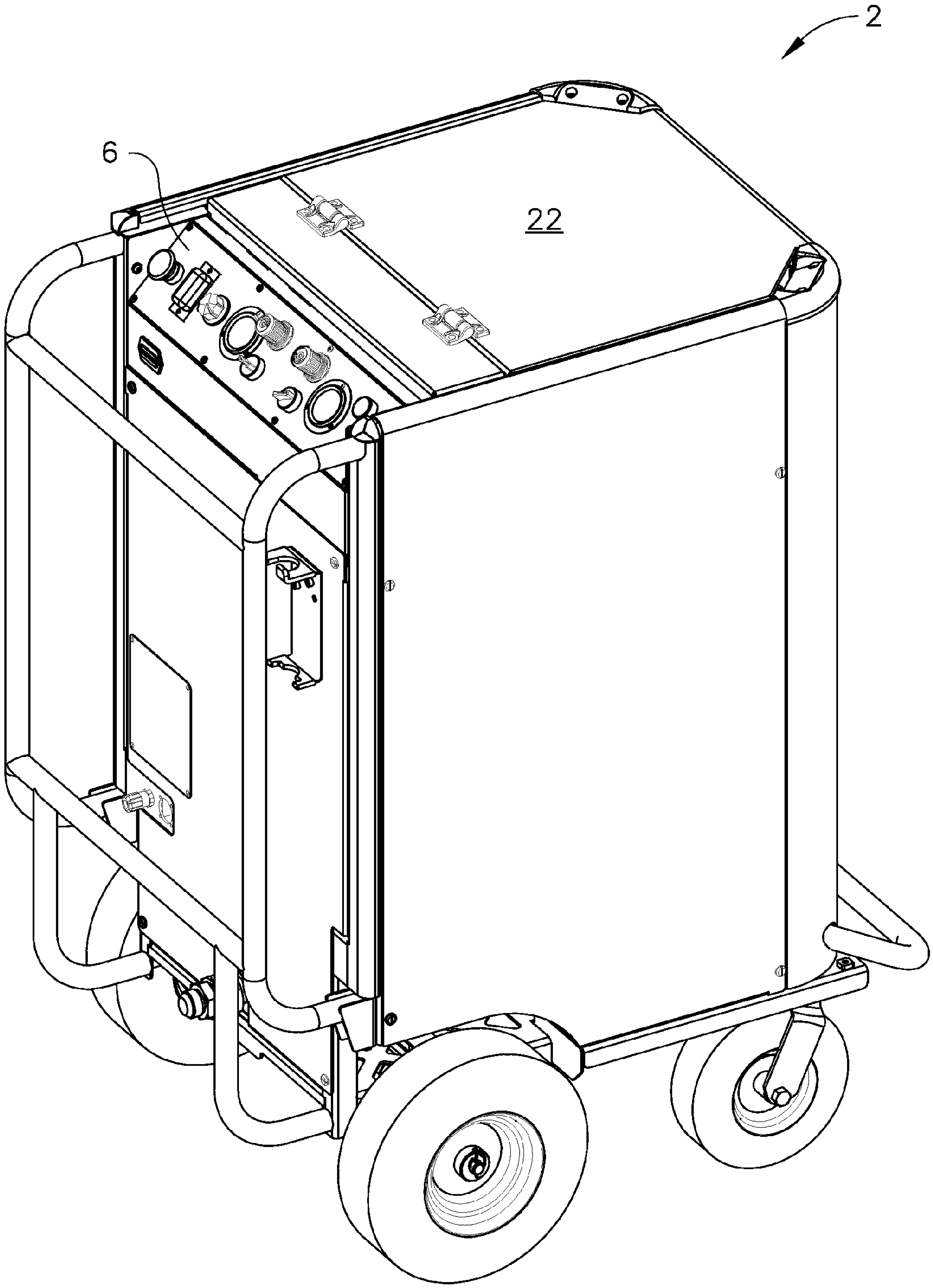


FIG. 1

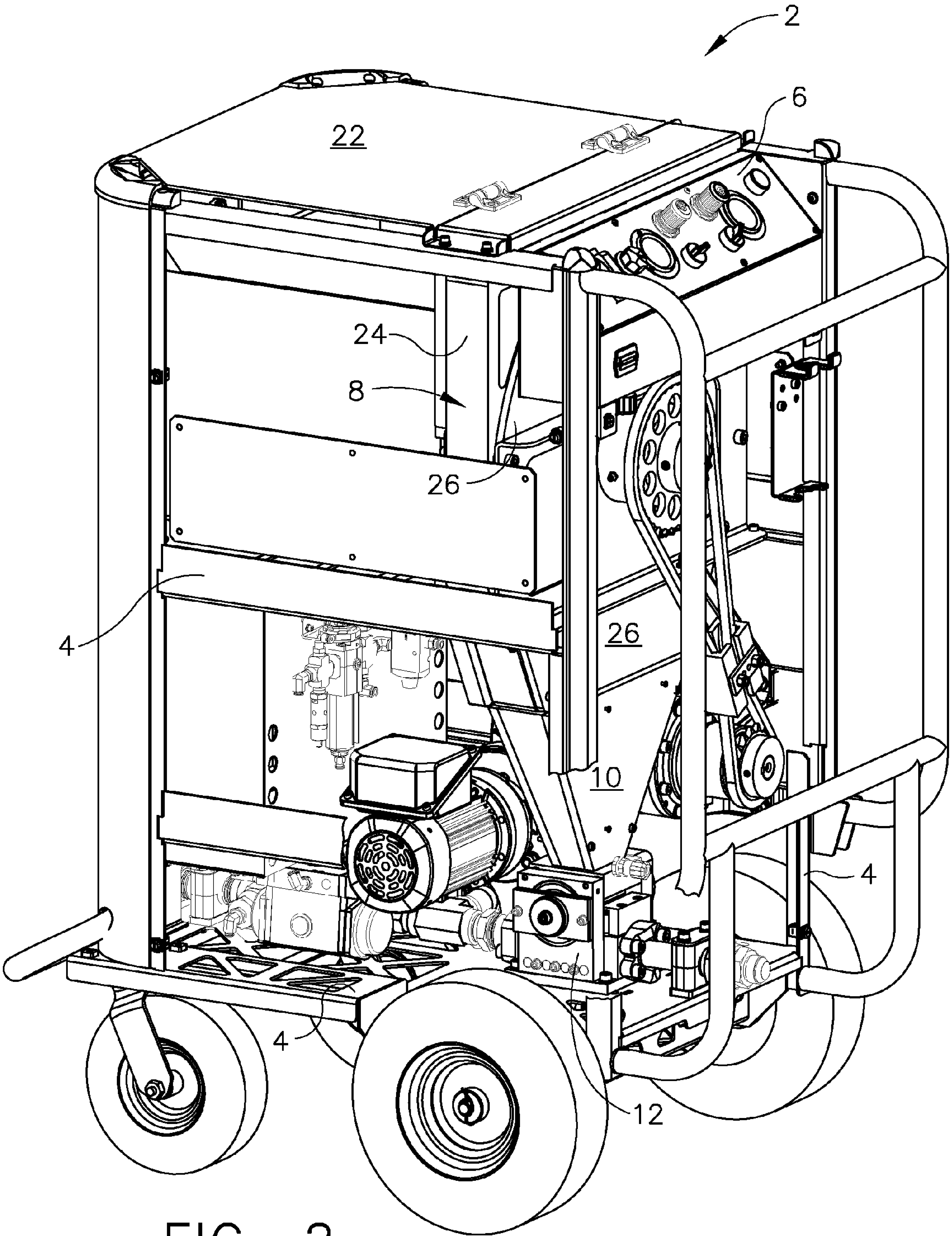
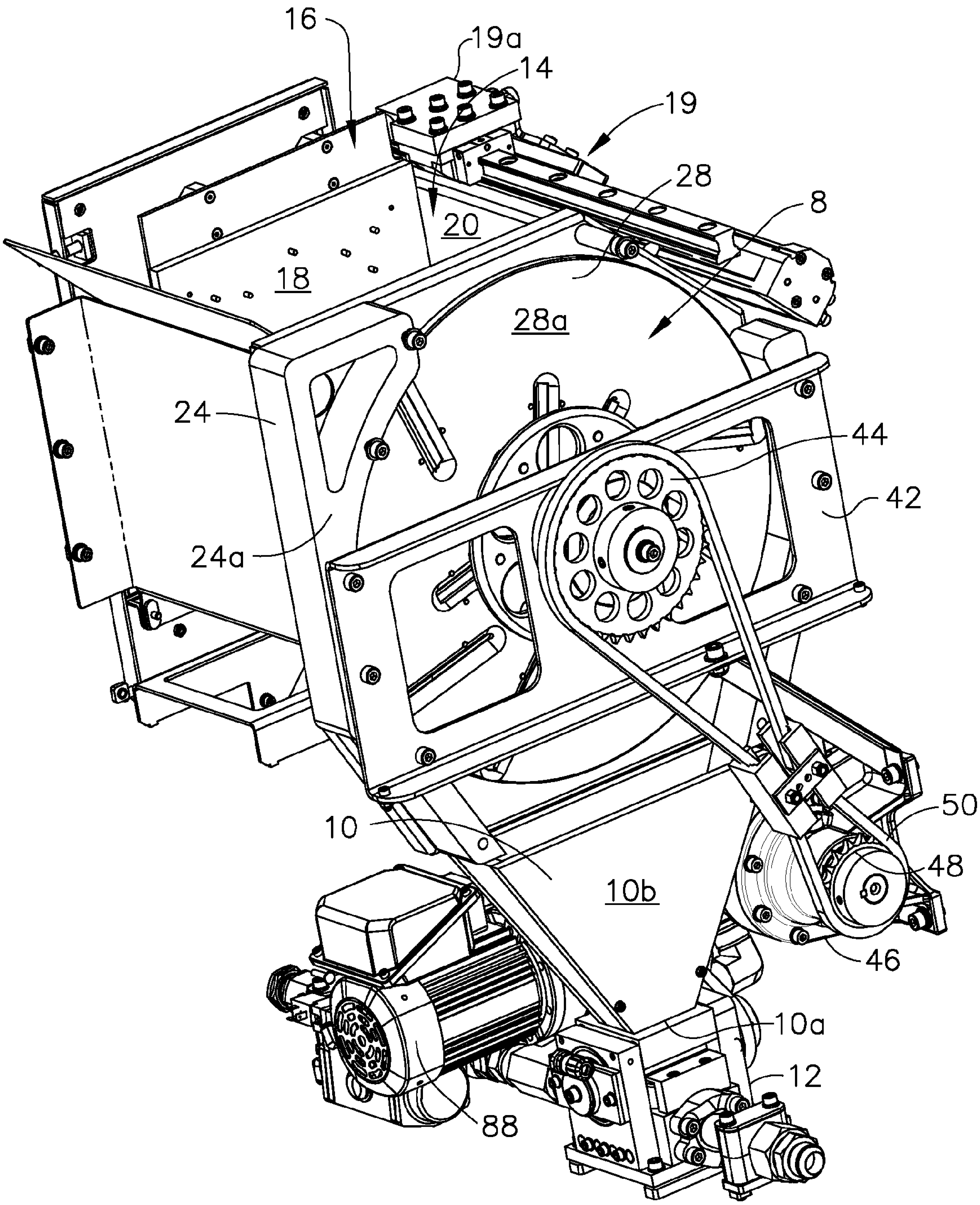


FIG. 2



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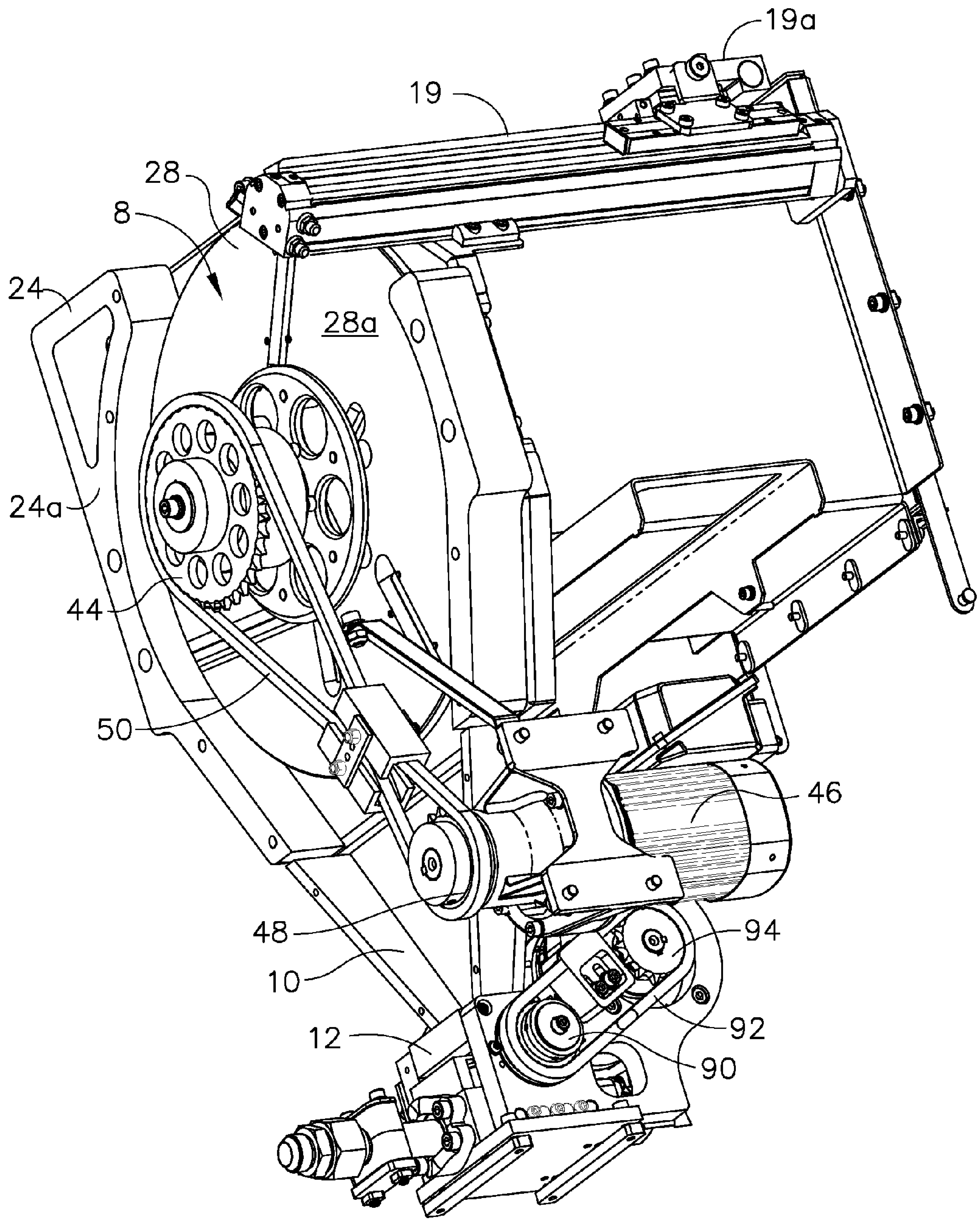

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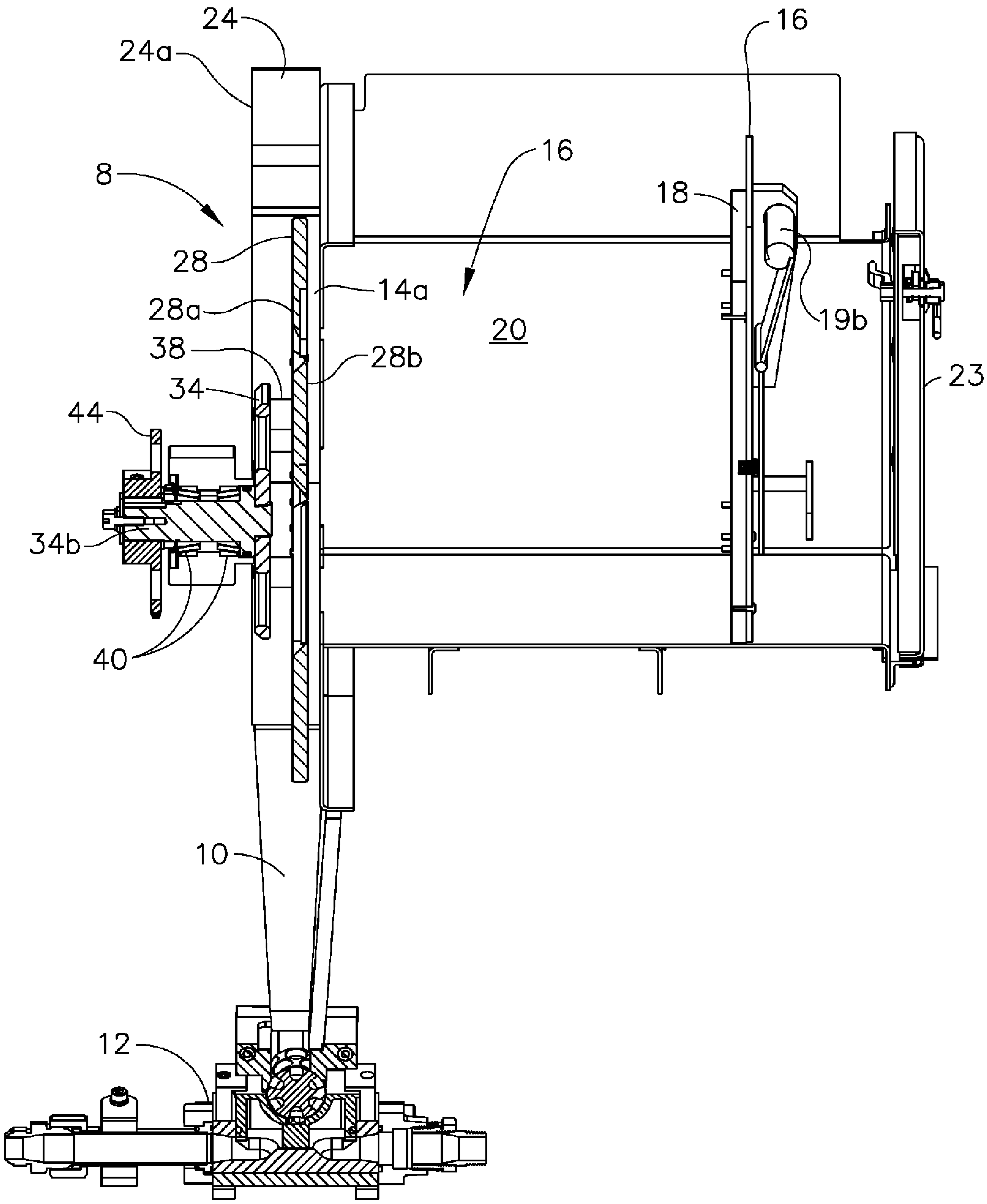
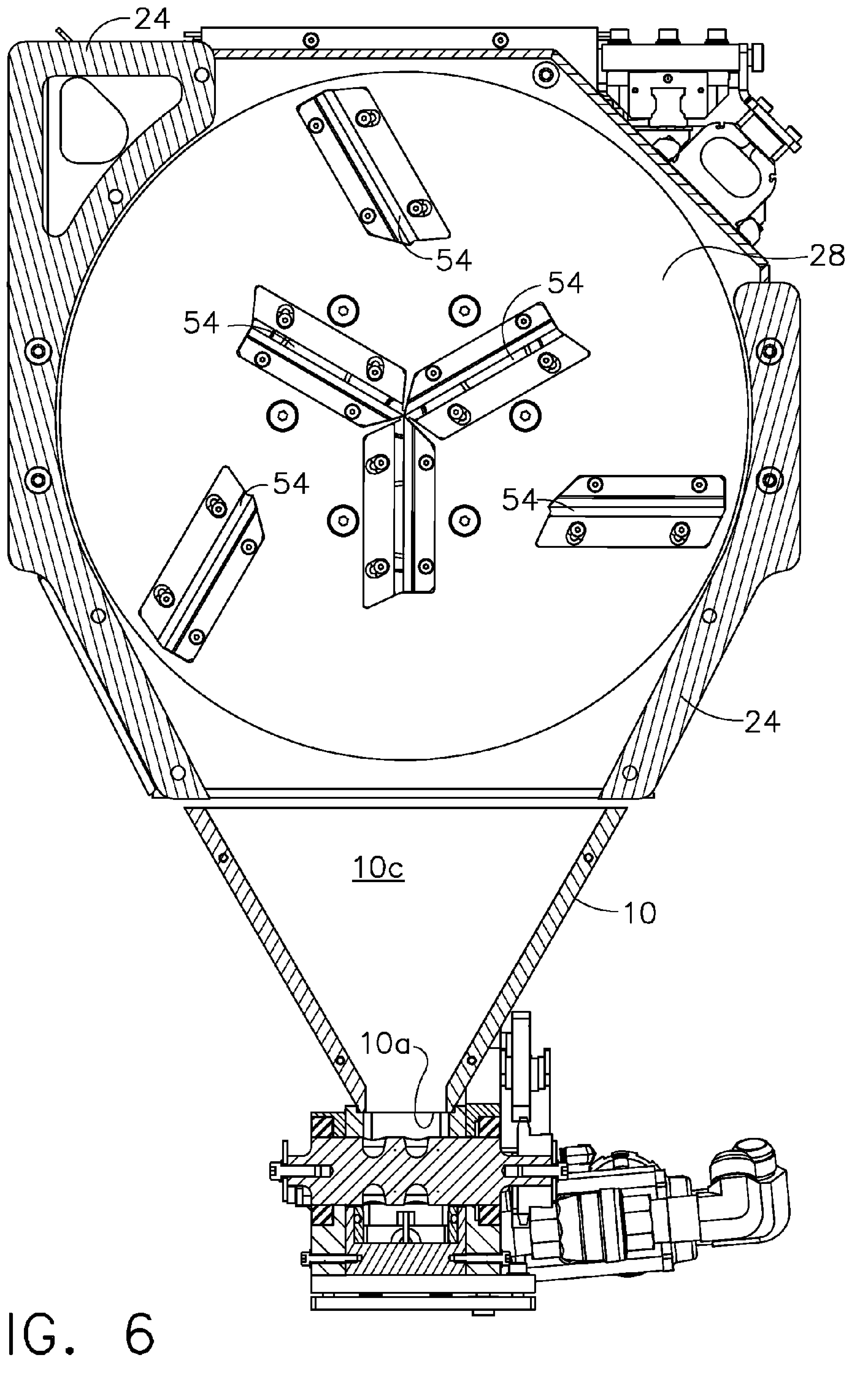


FIG. 5



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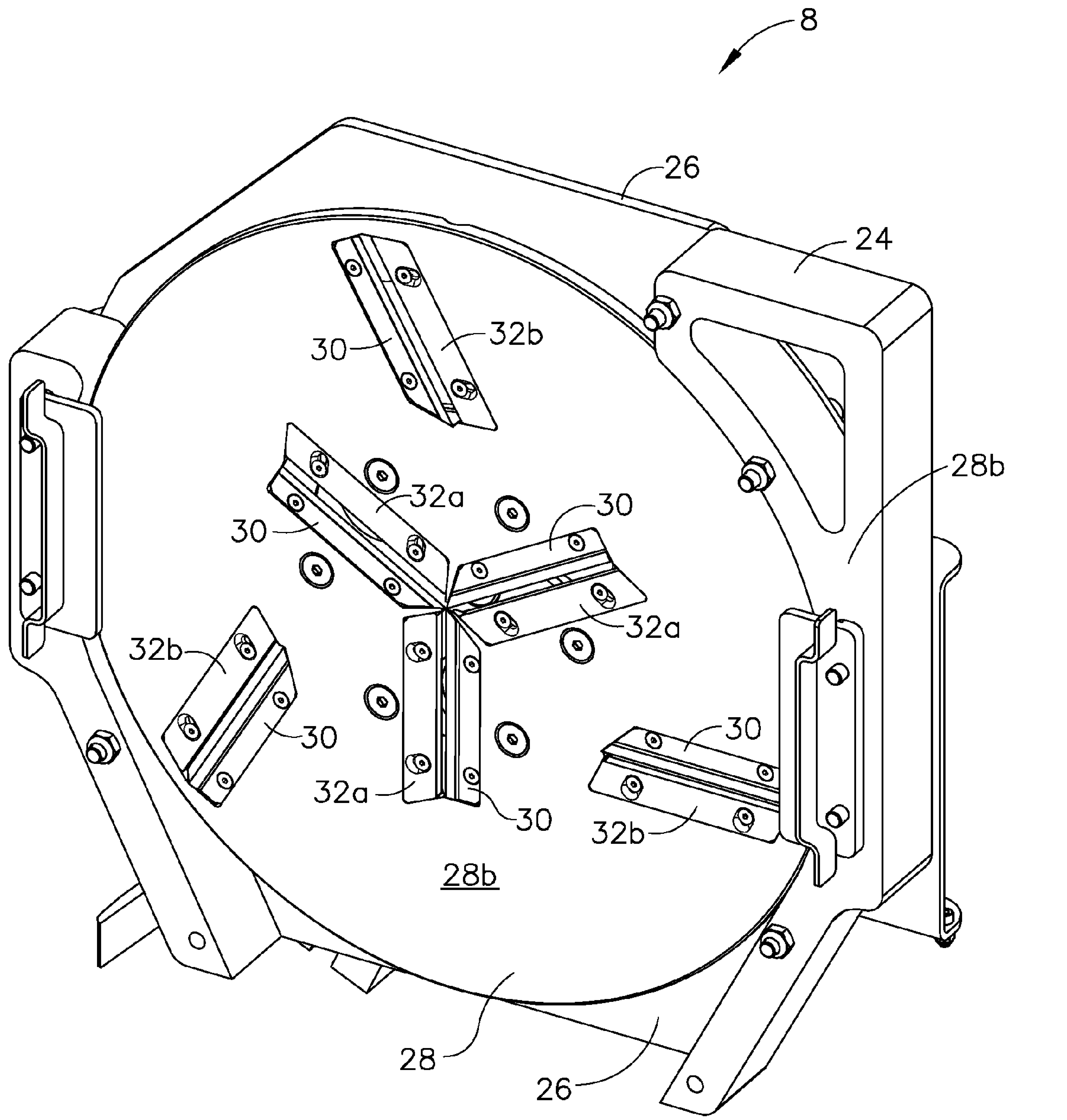

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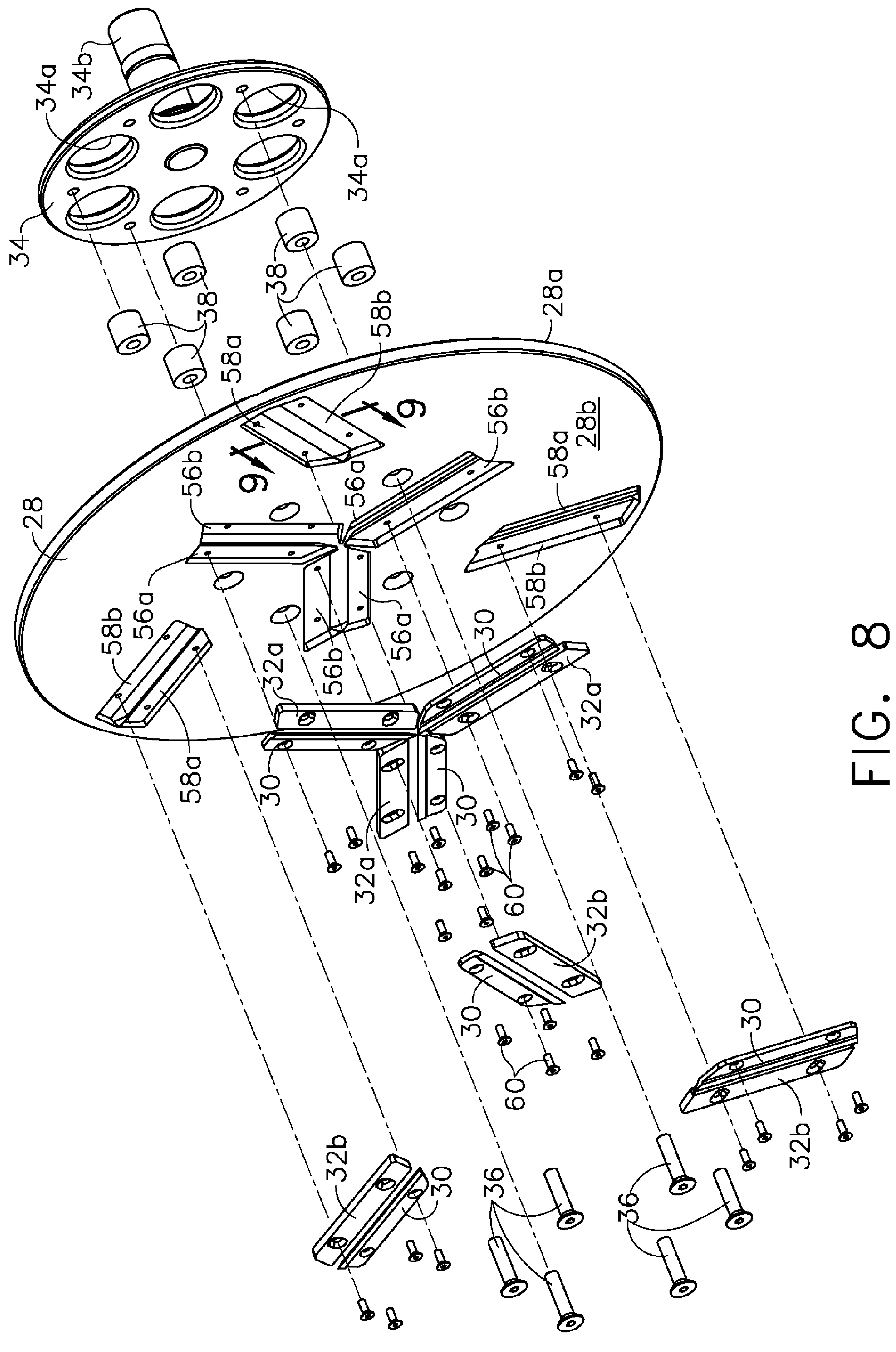

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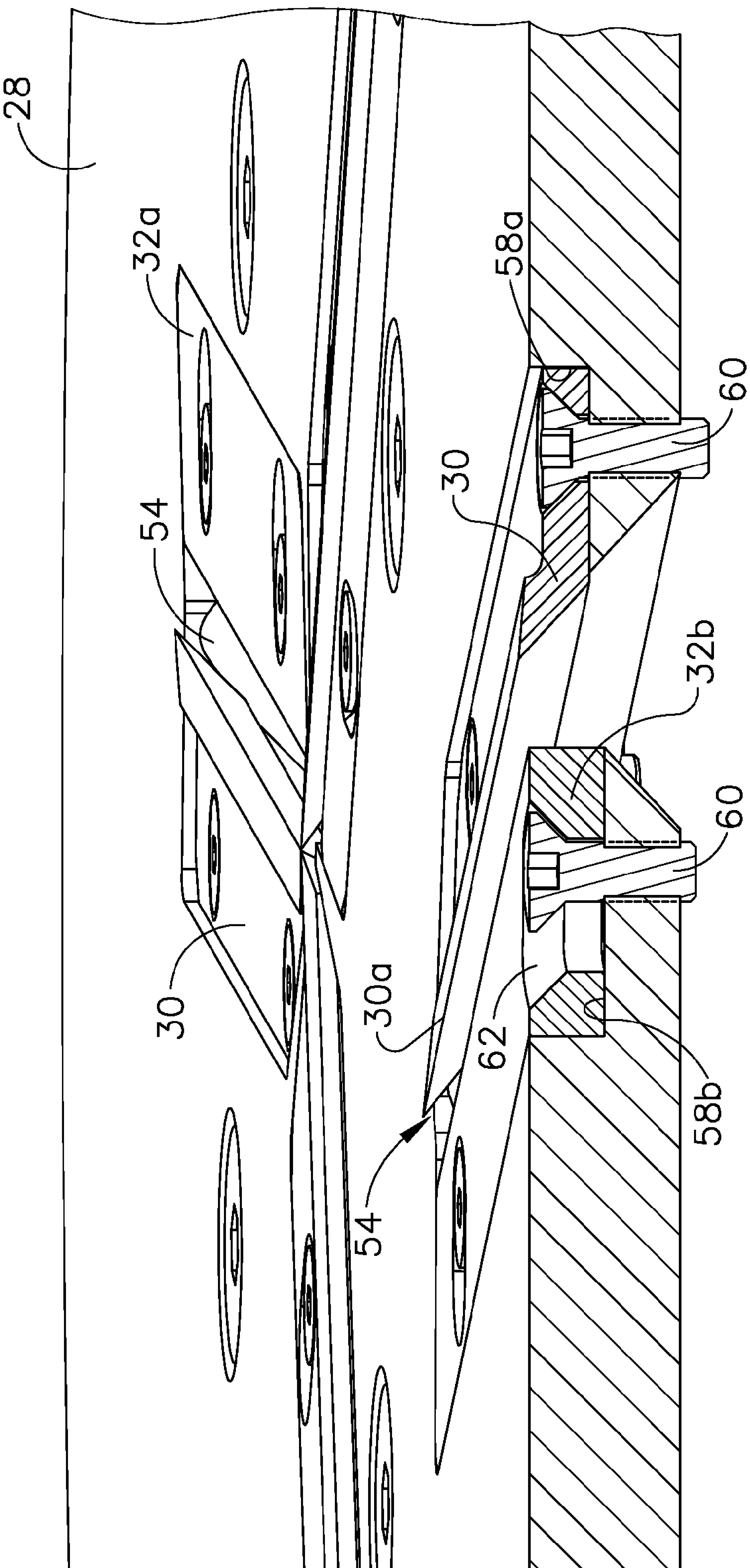
FIG. 8



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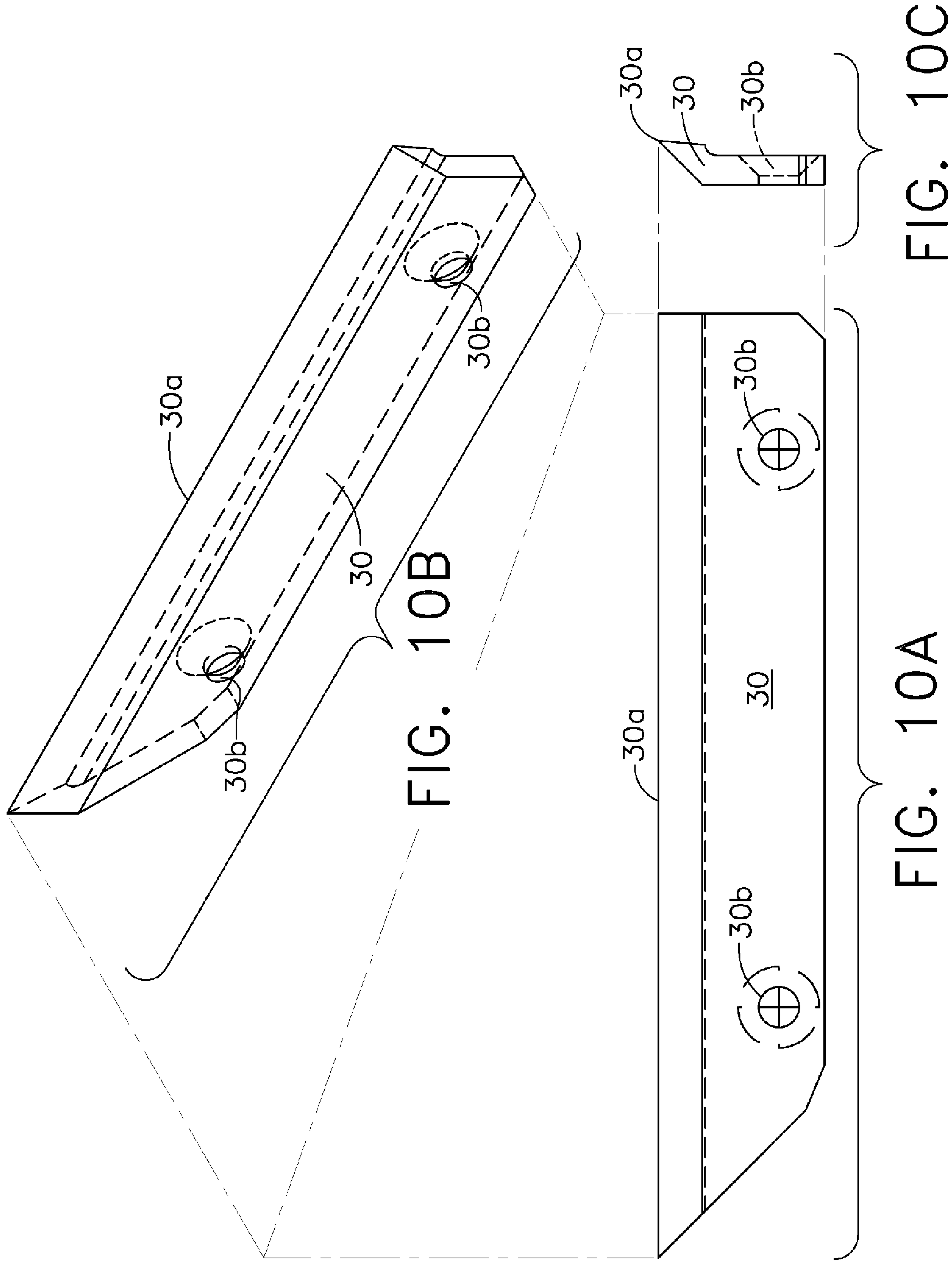


FIG. 10B

FIG. 10A

FIG. 10C

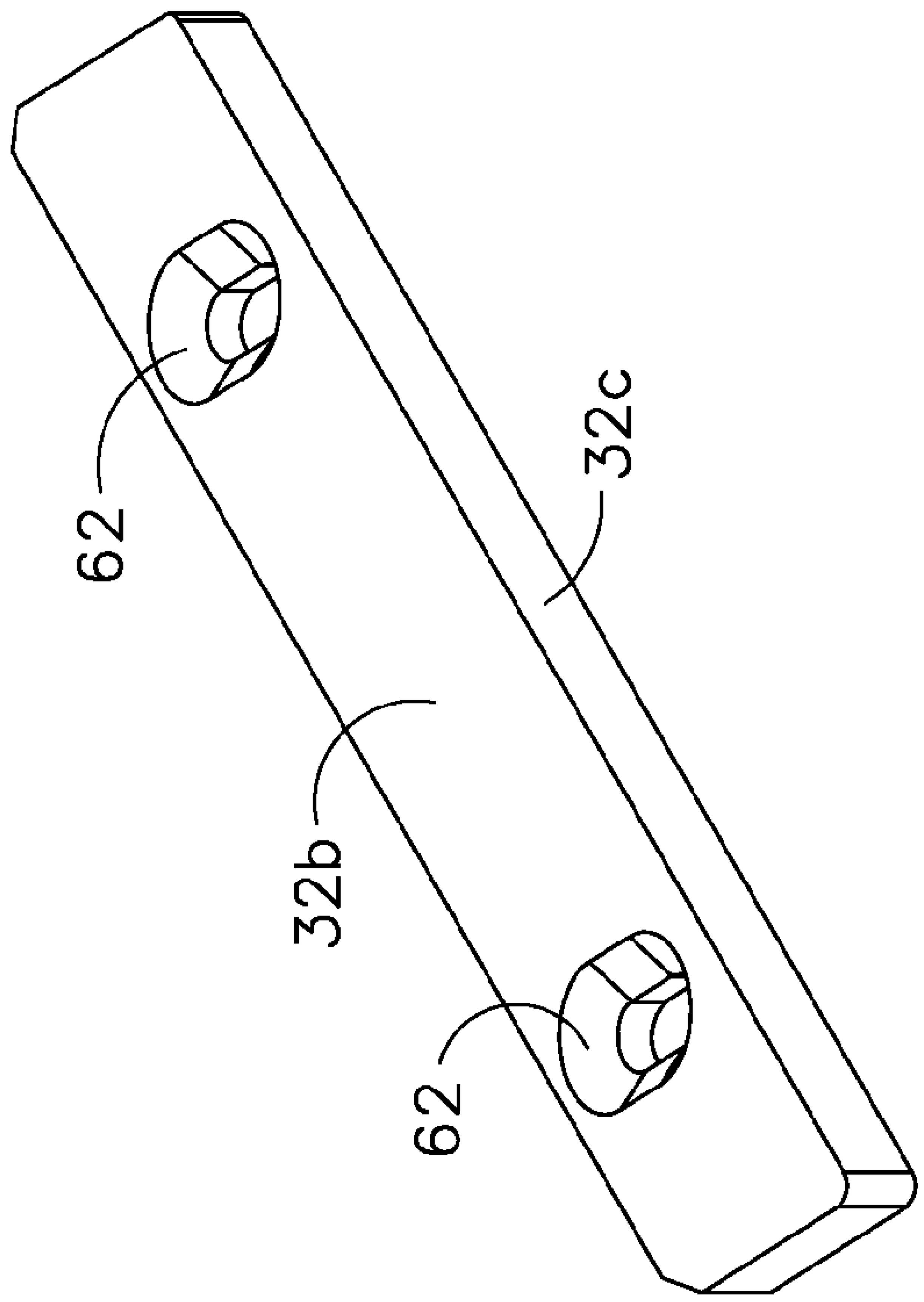
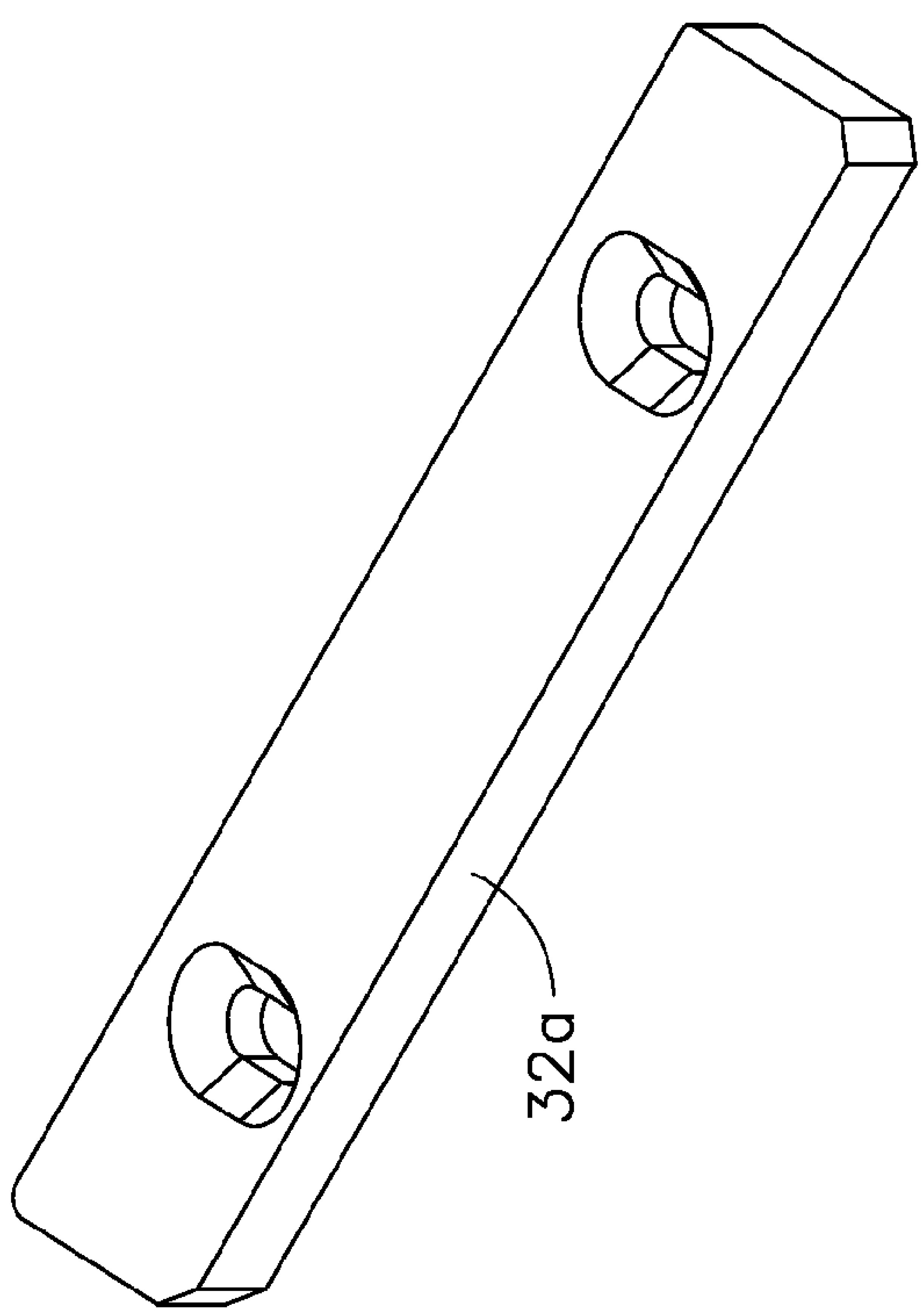


FIG. 12



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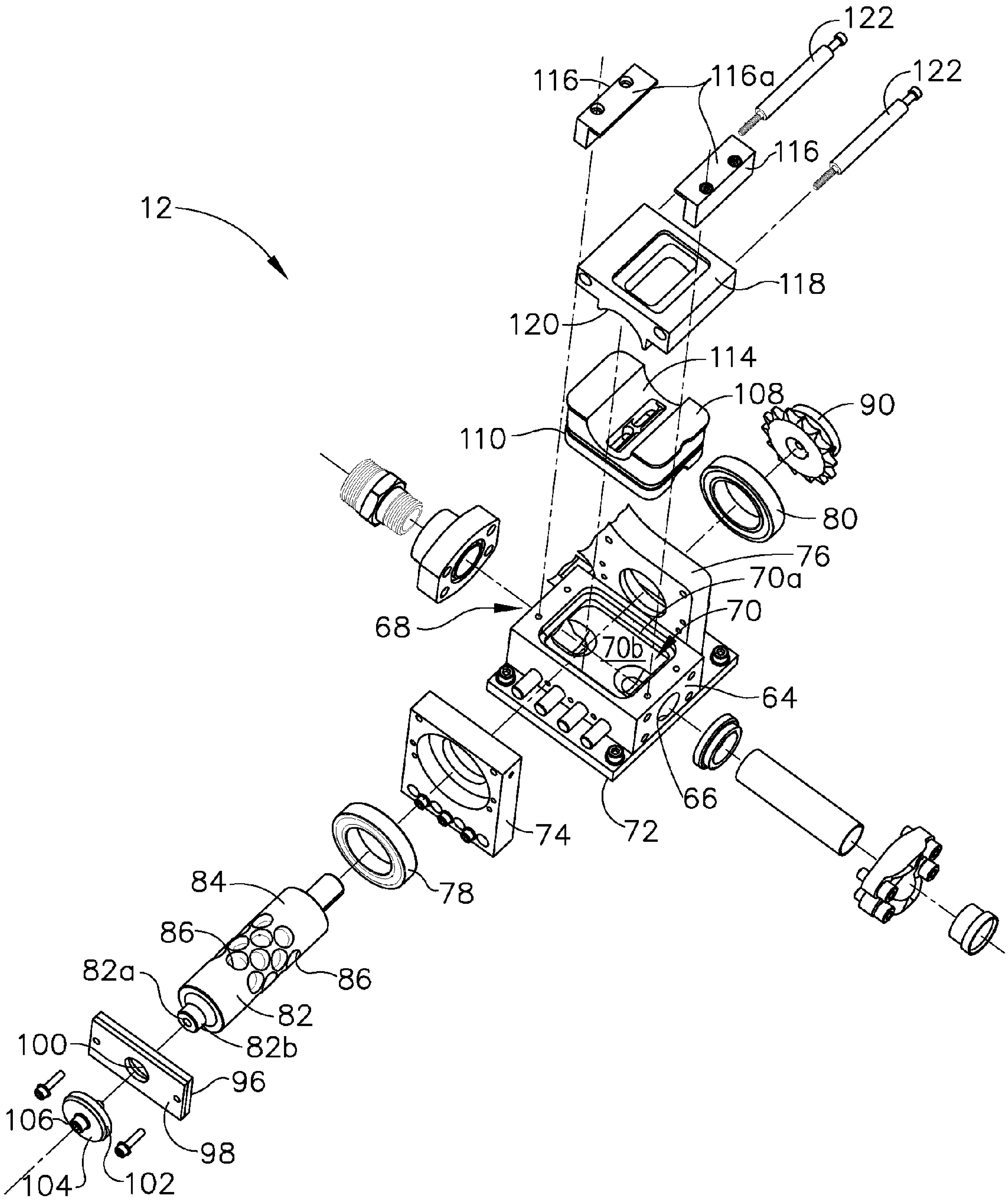
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FIG. 13

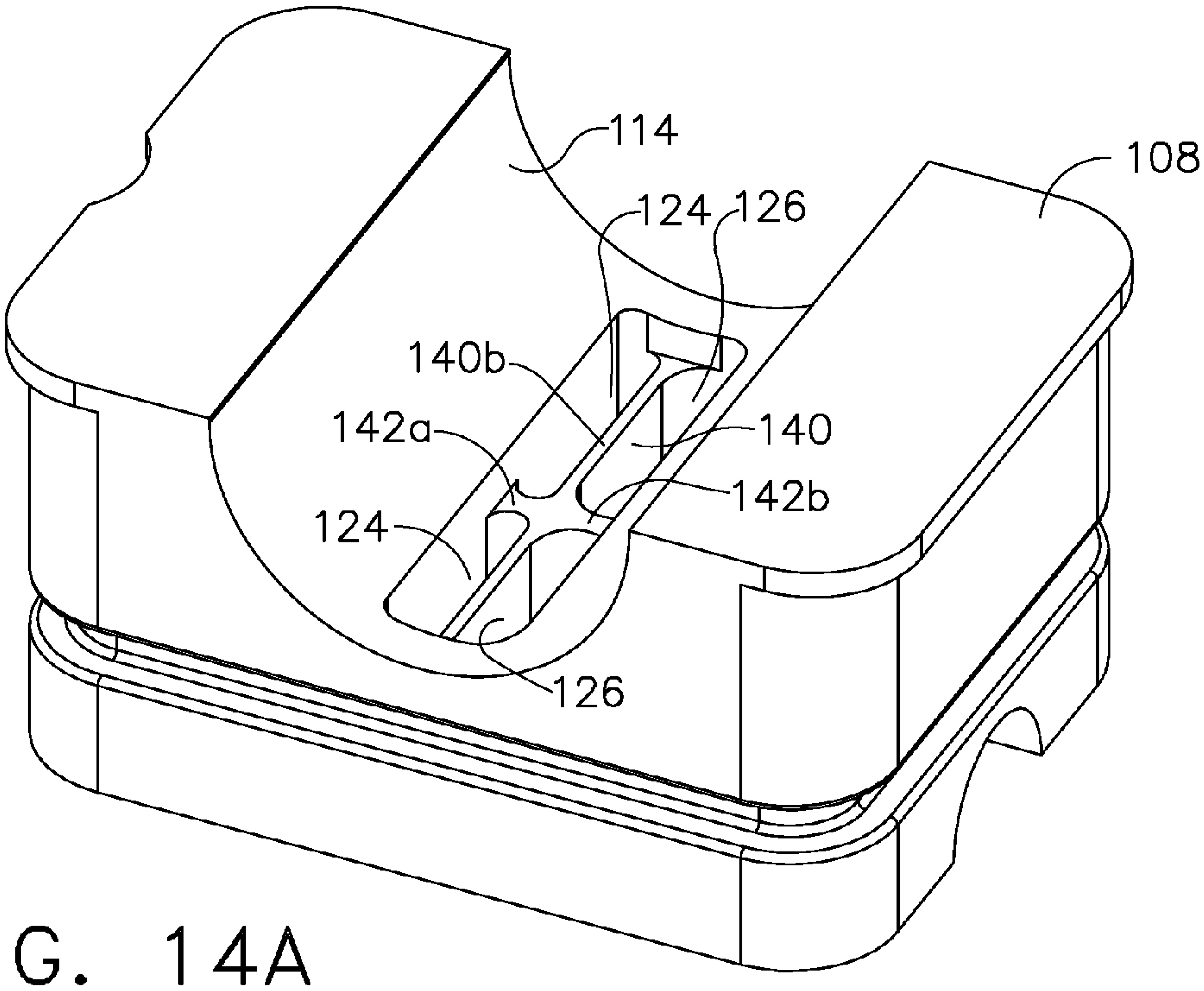

FIG. 14A

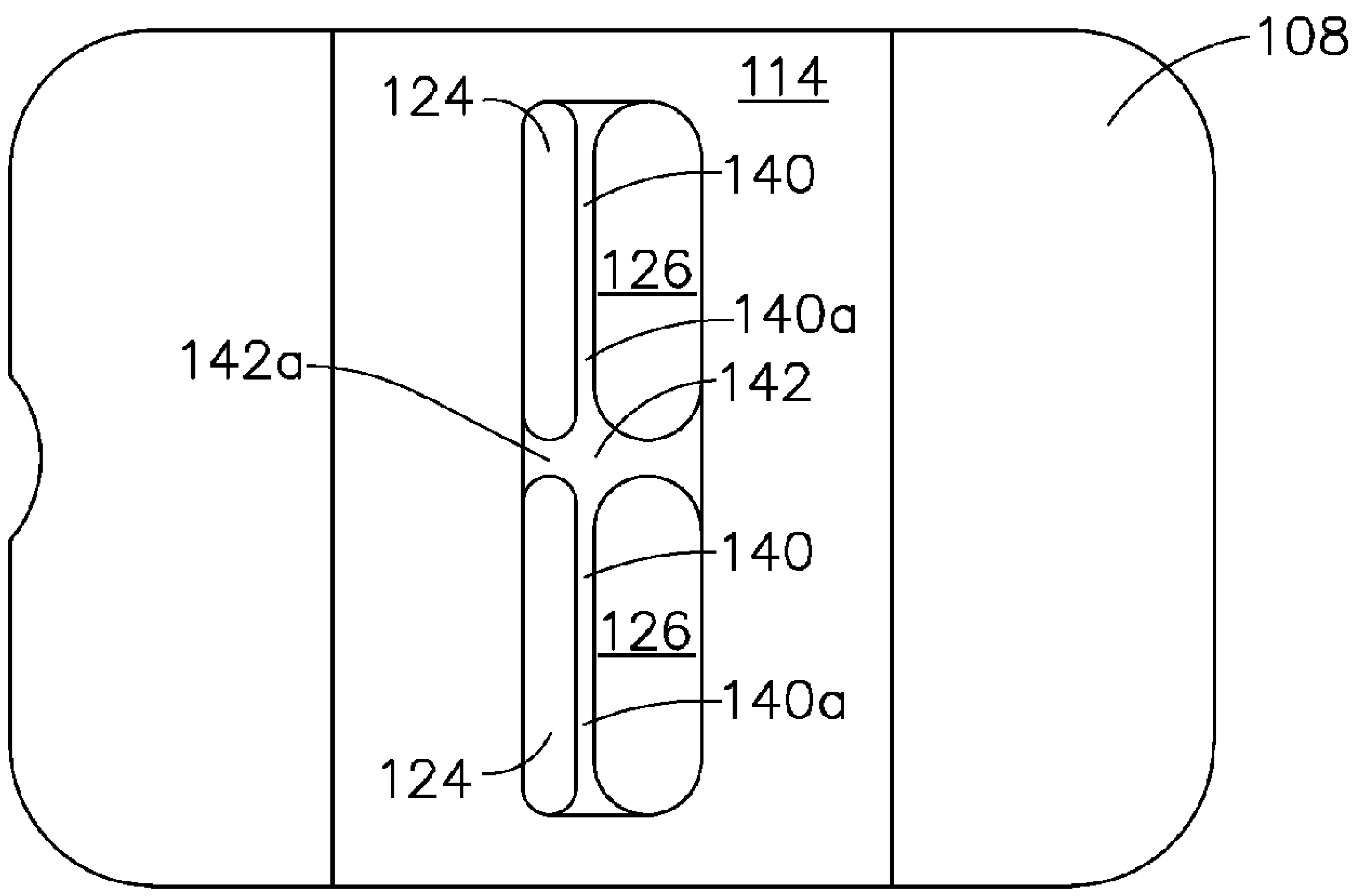

FIG. 14B

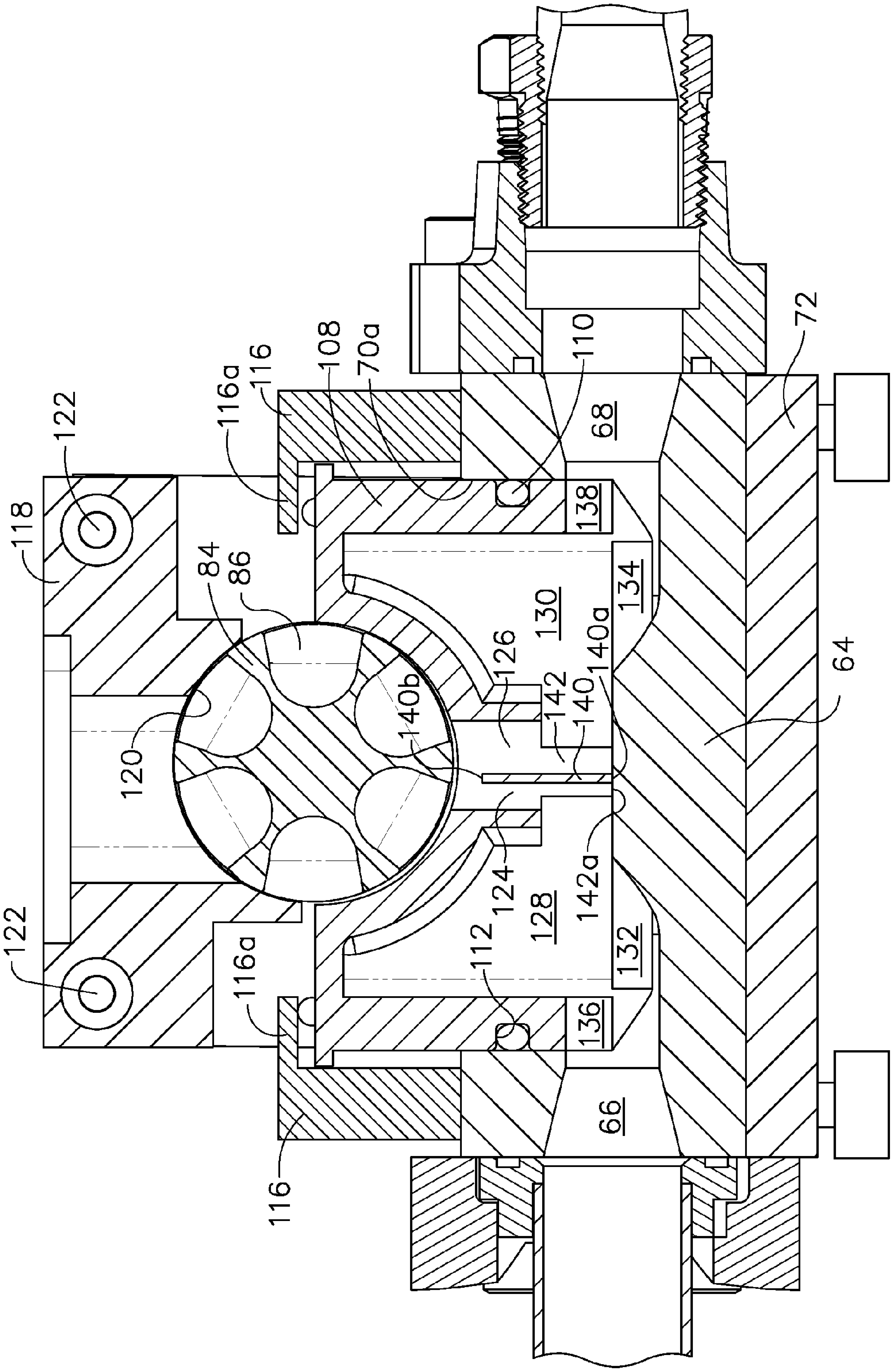
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FIG. 15

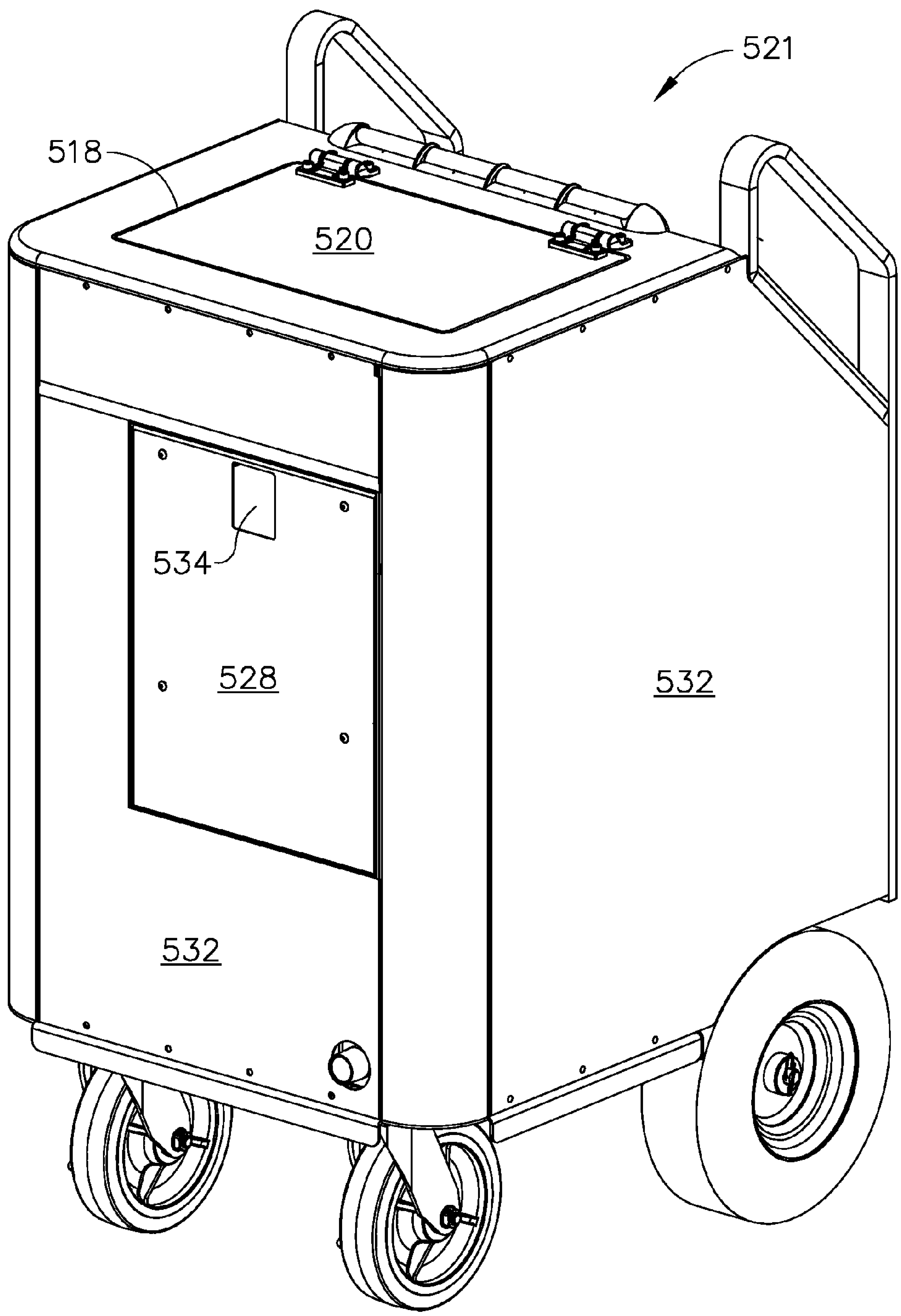
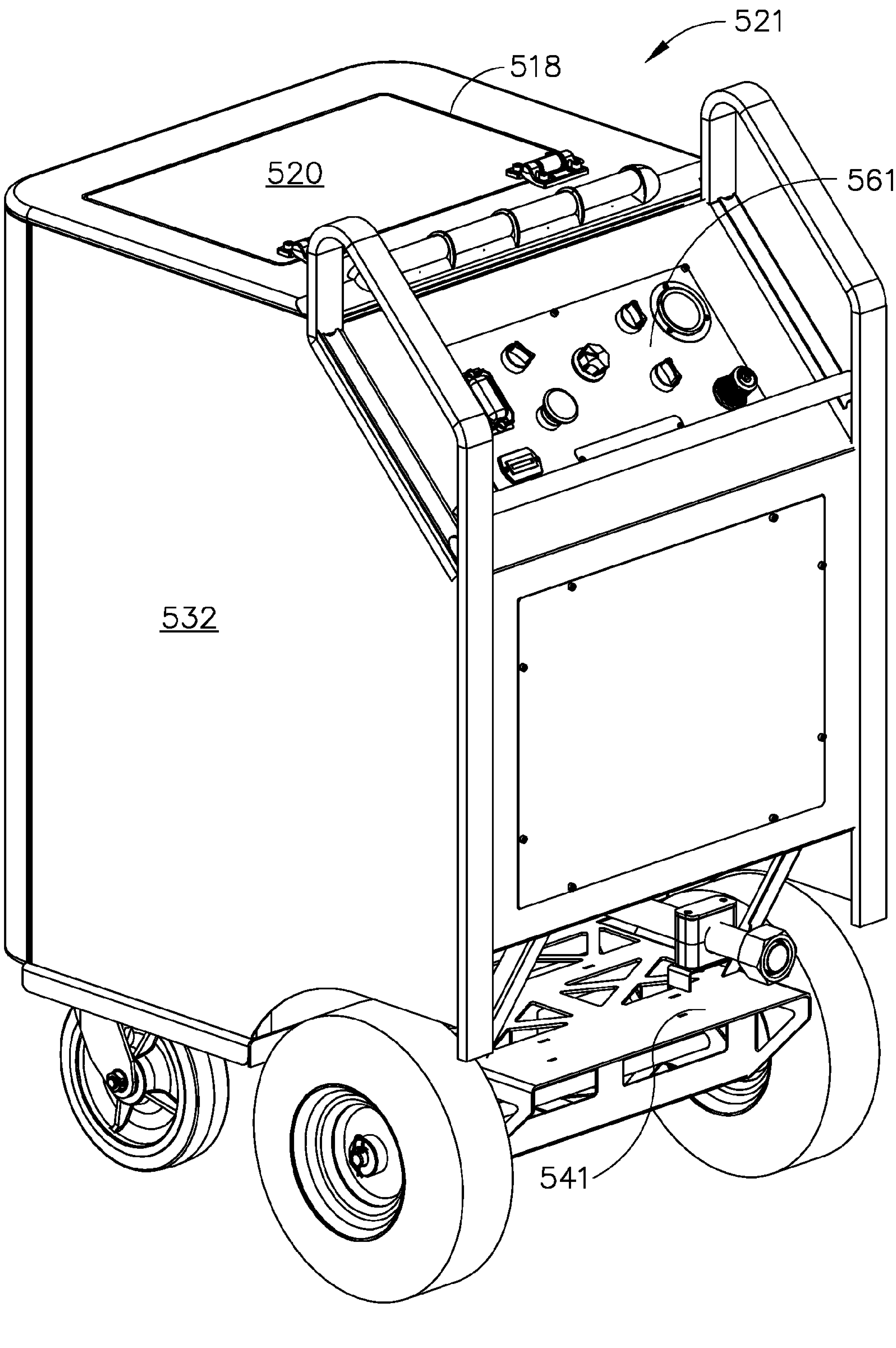


FIG. 16



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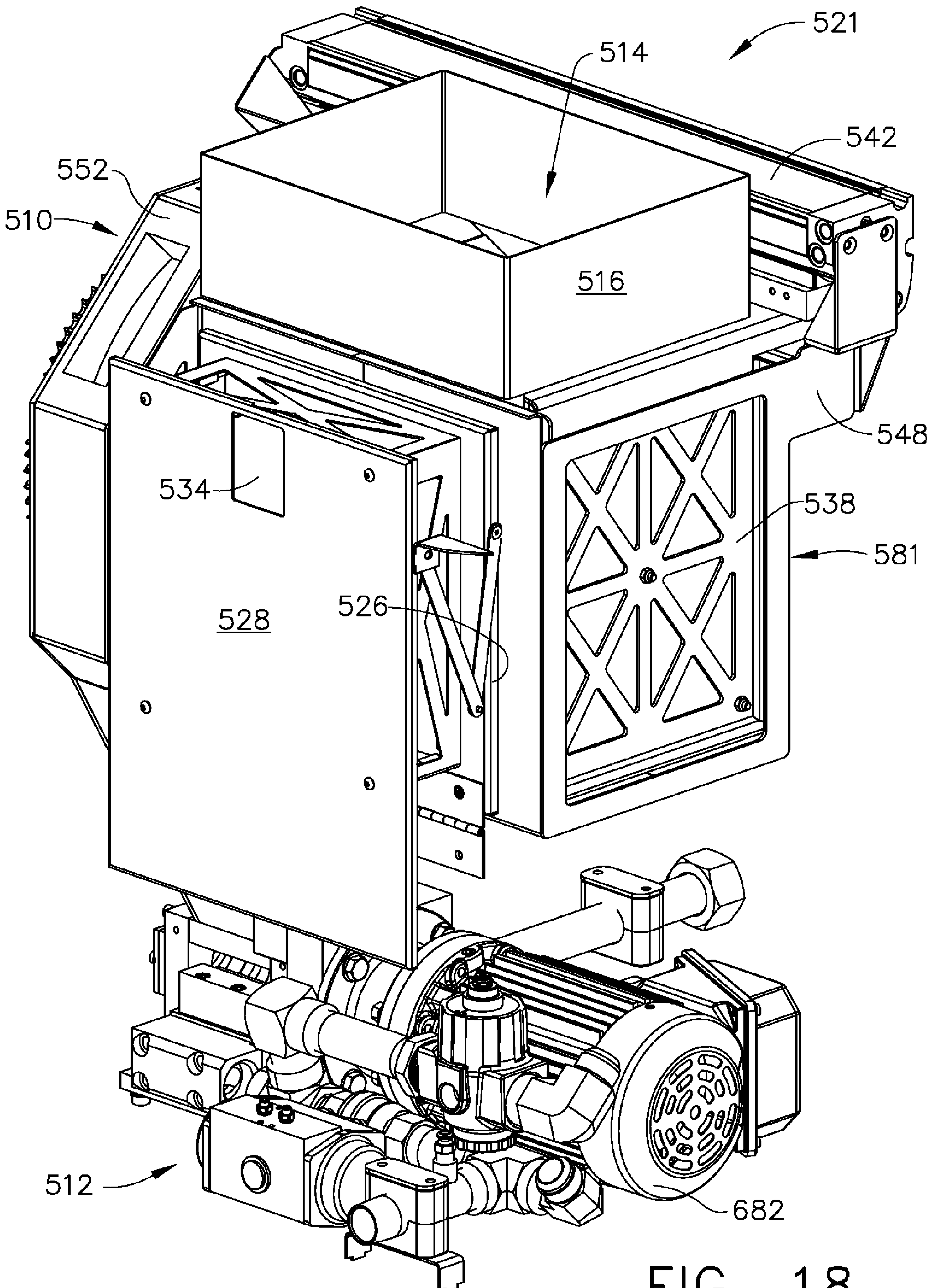

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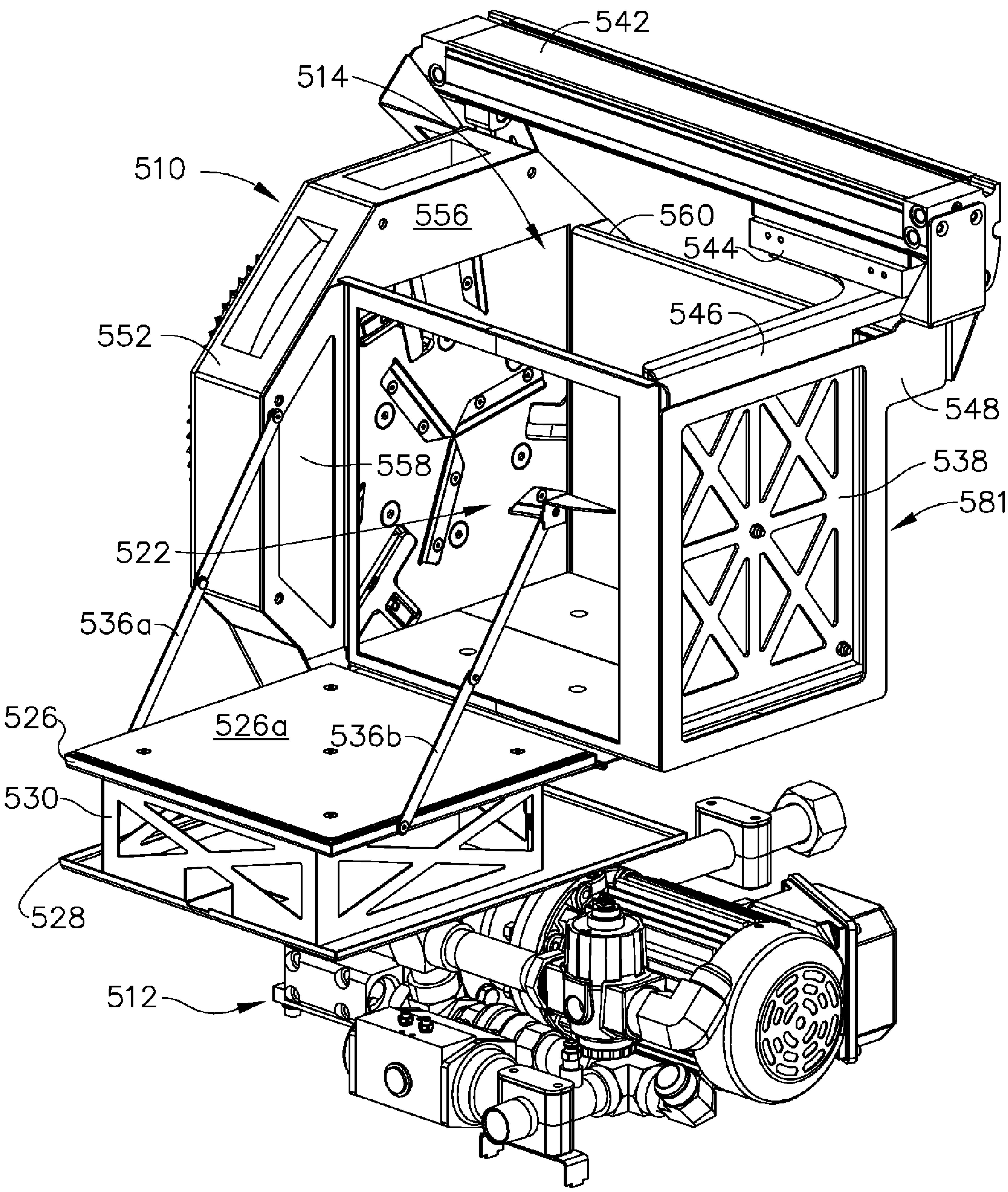
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FIG. 19

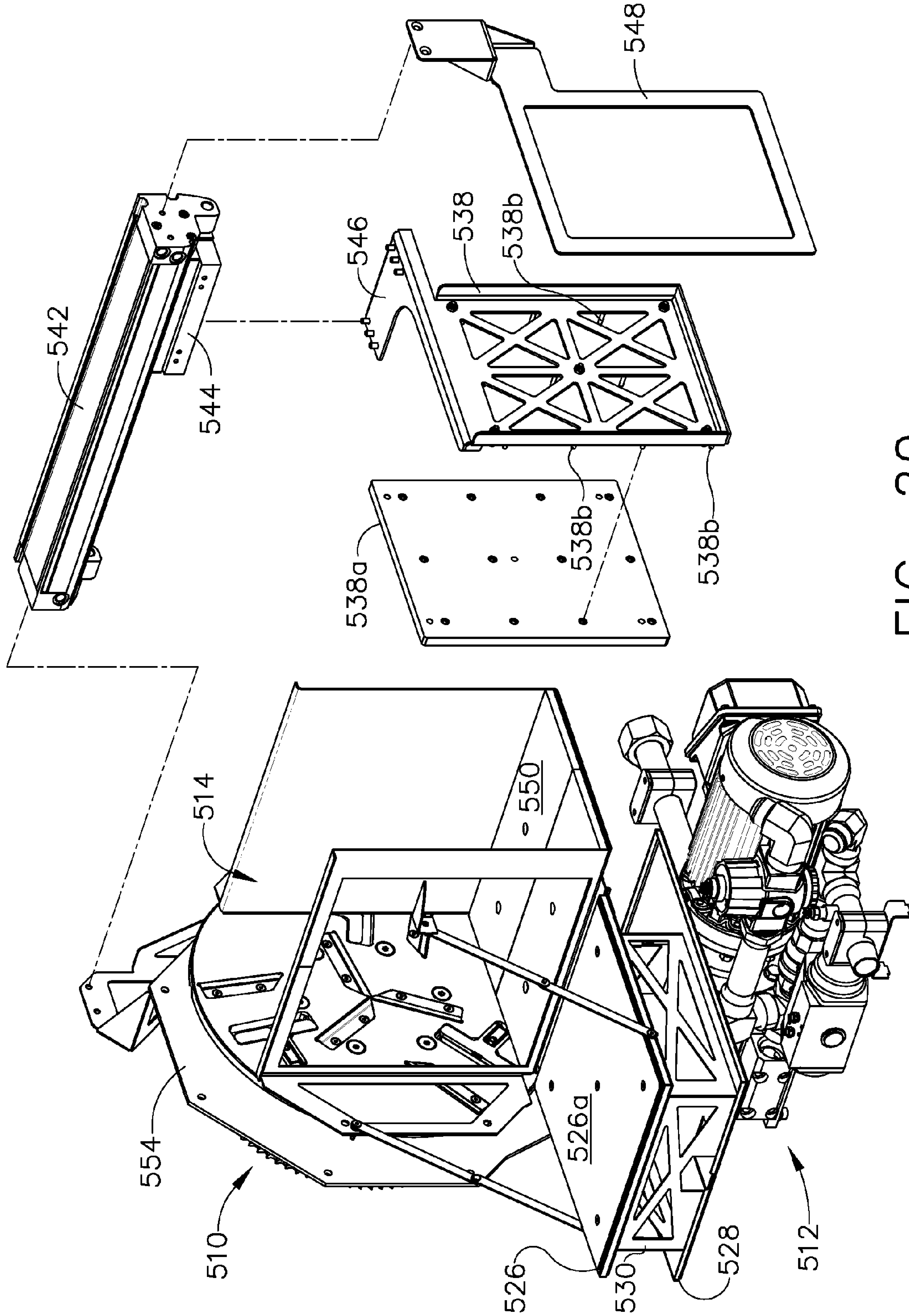
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FIG. 20

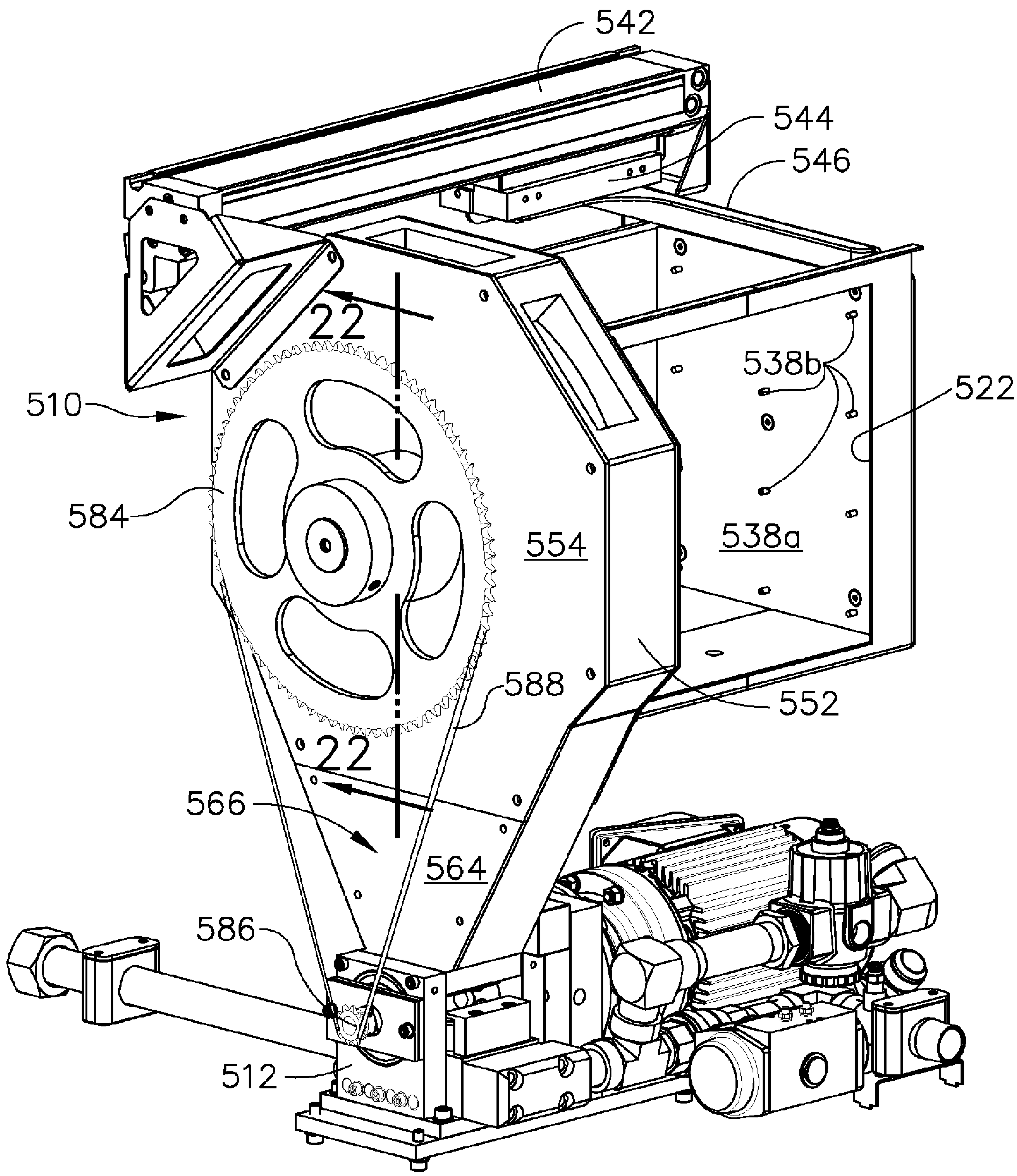
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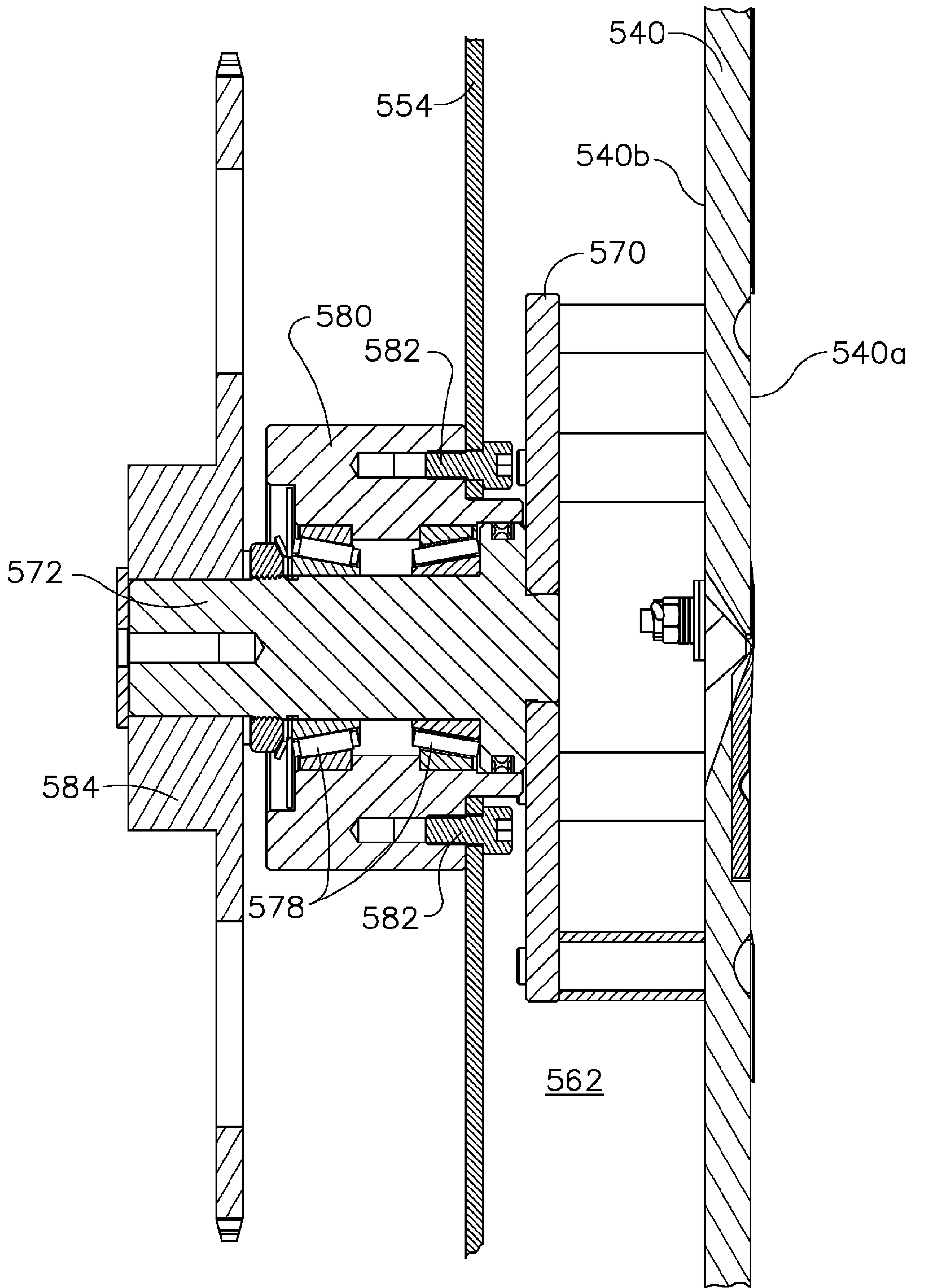
FIG. 21



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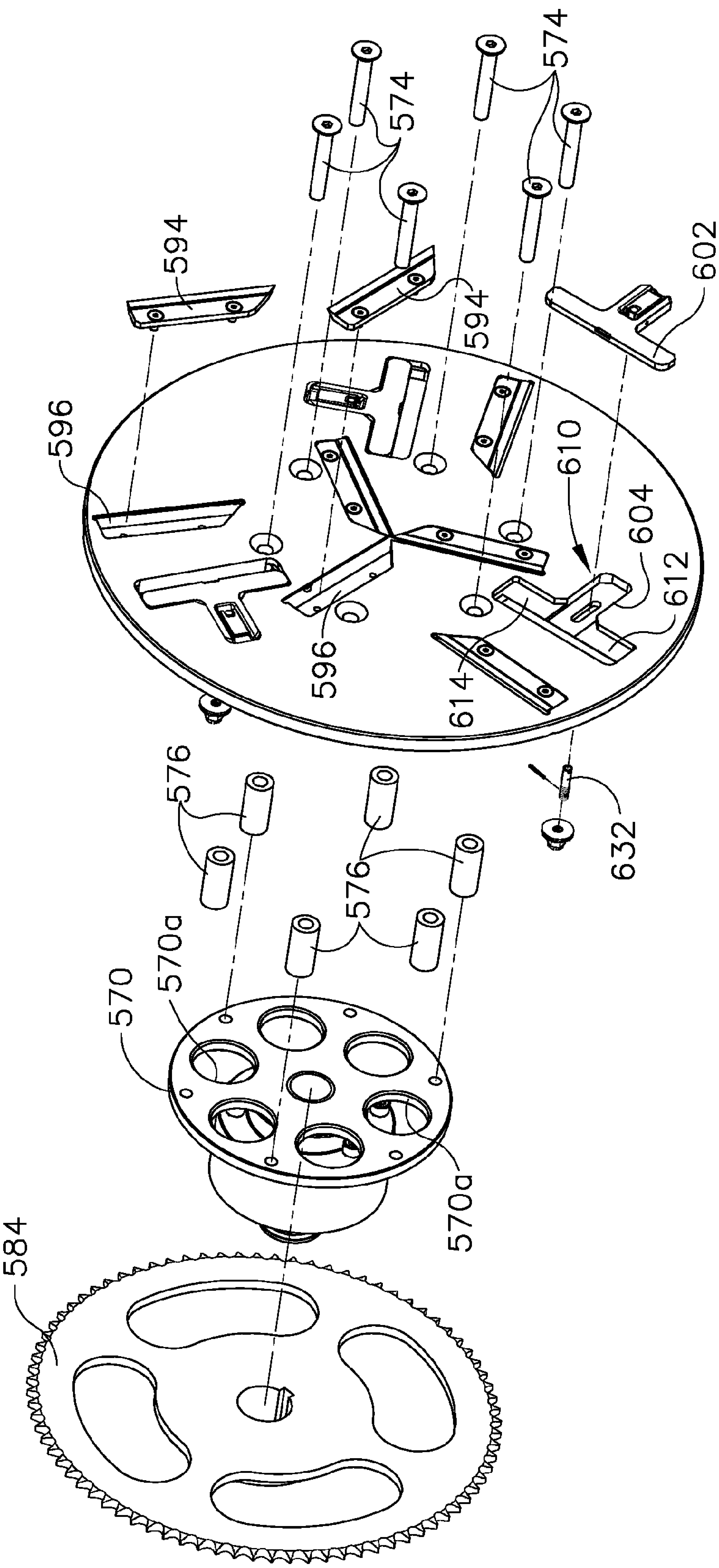
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FIG. 23

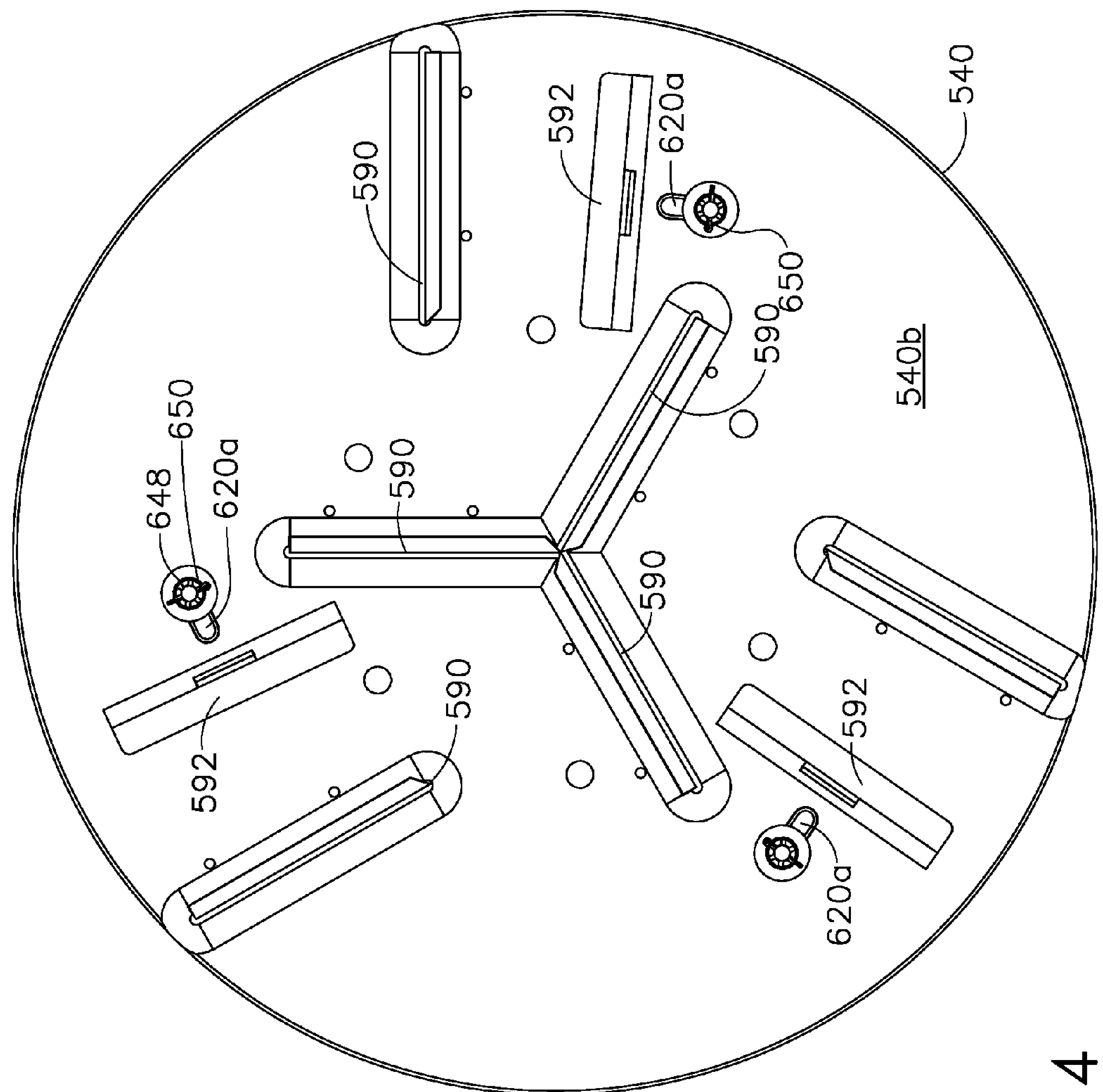
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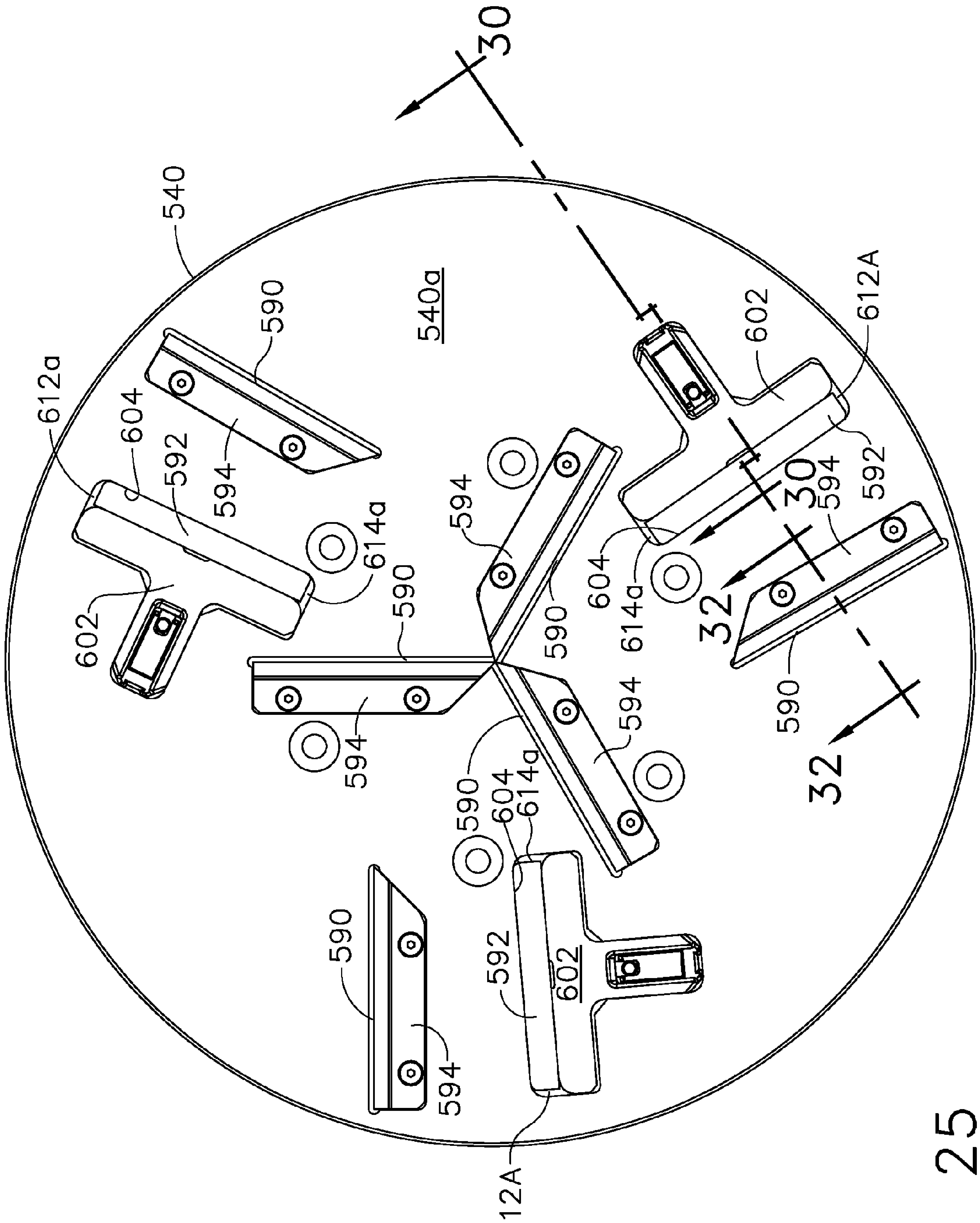
FIG. 24



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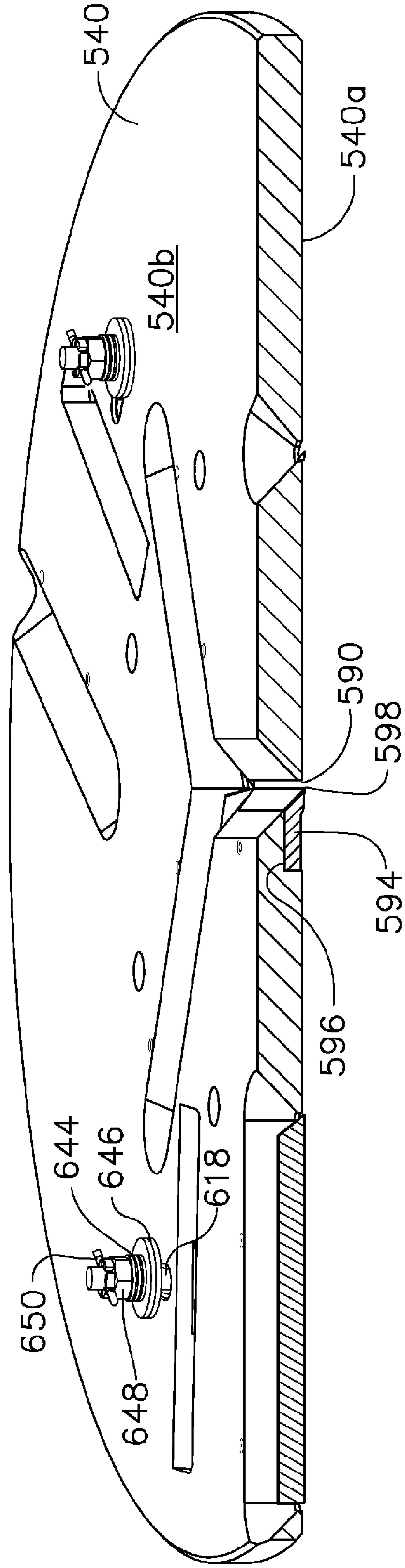

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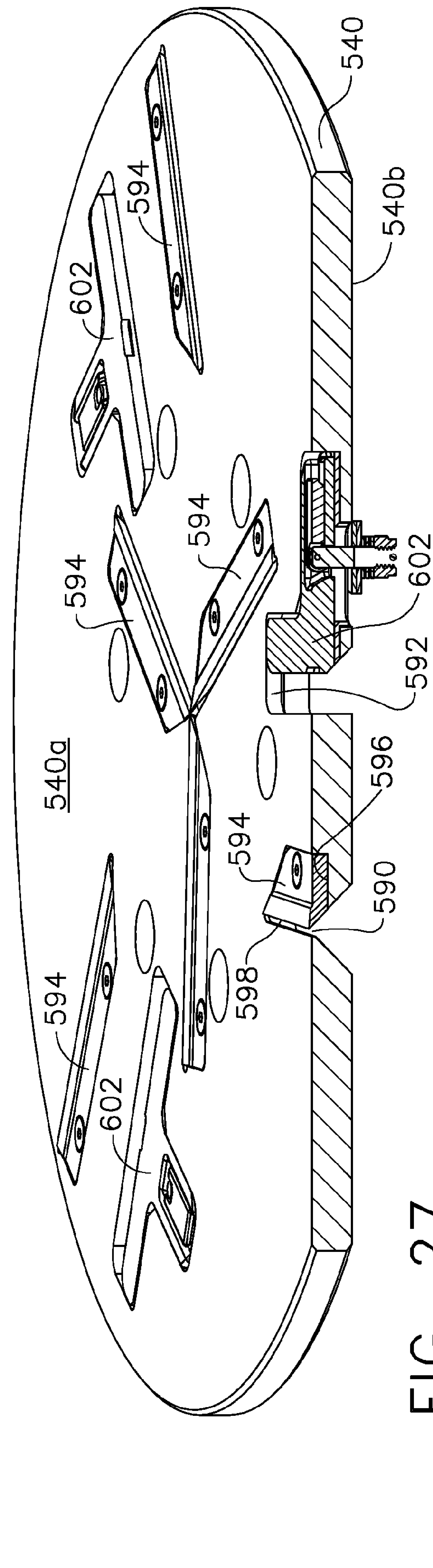

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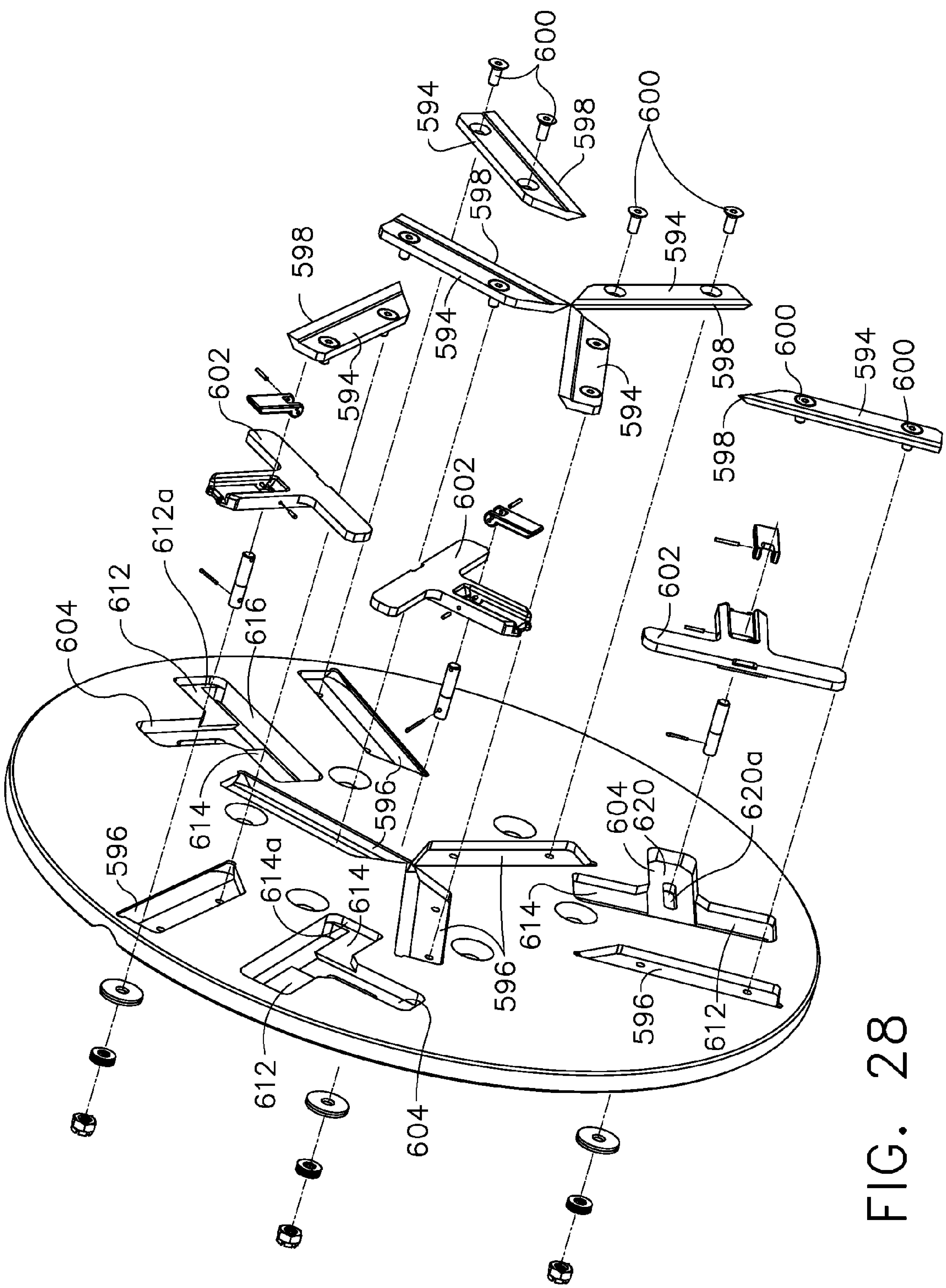

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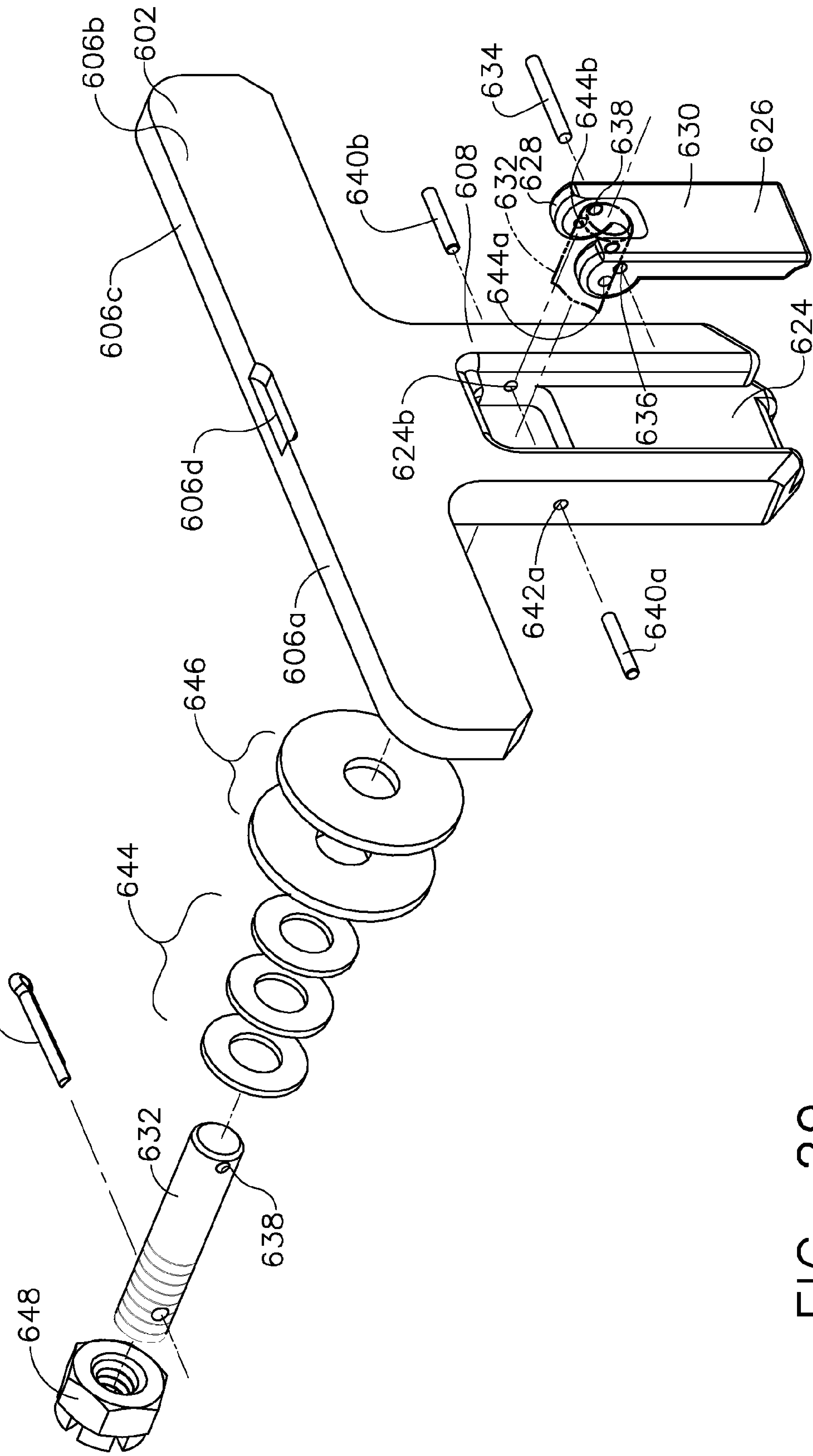
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FIG. 29

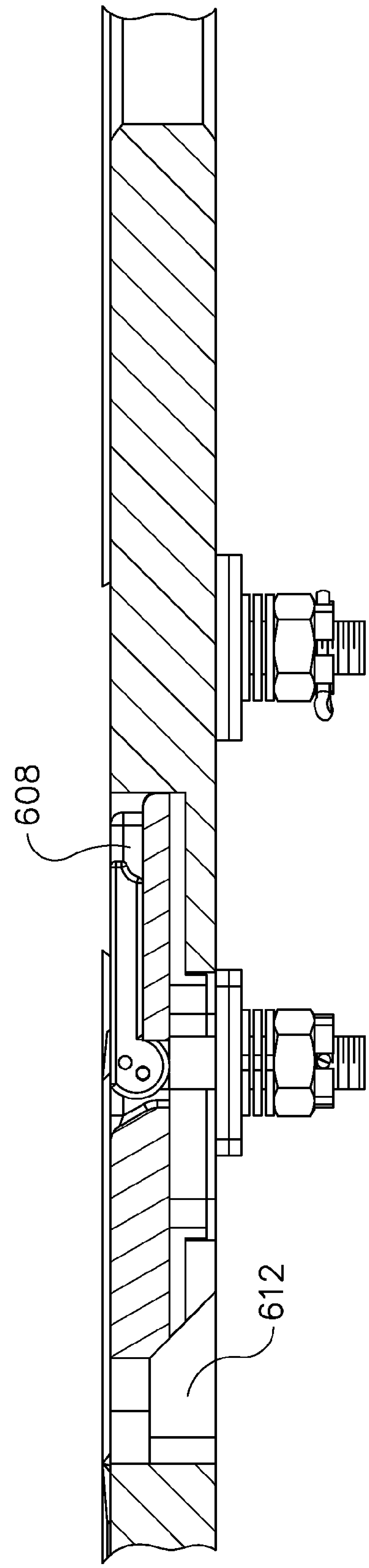

FIG. 30

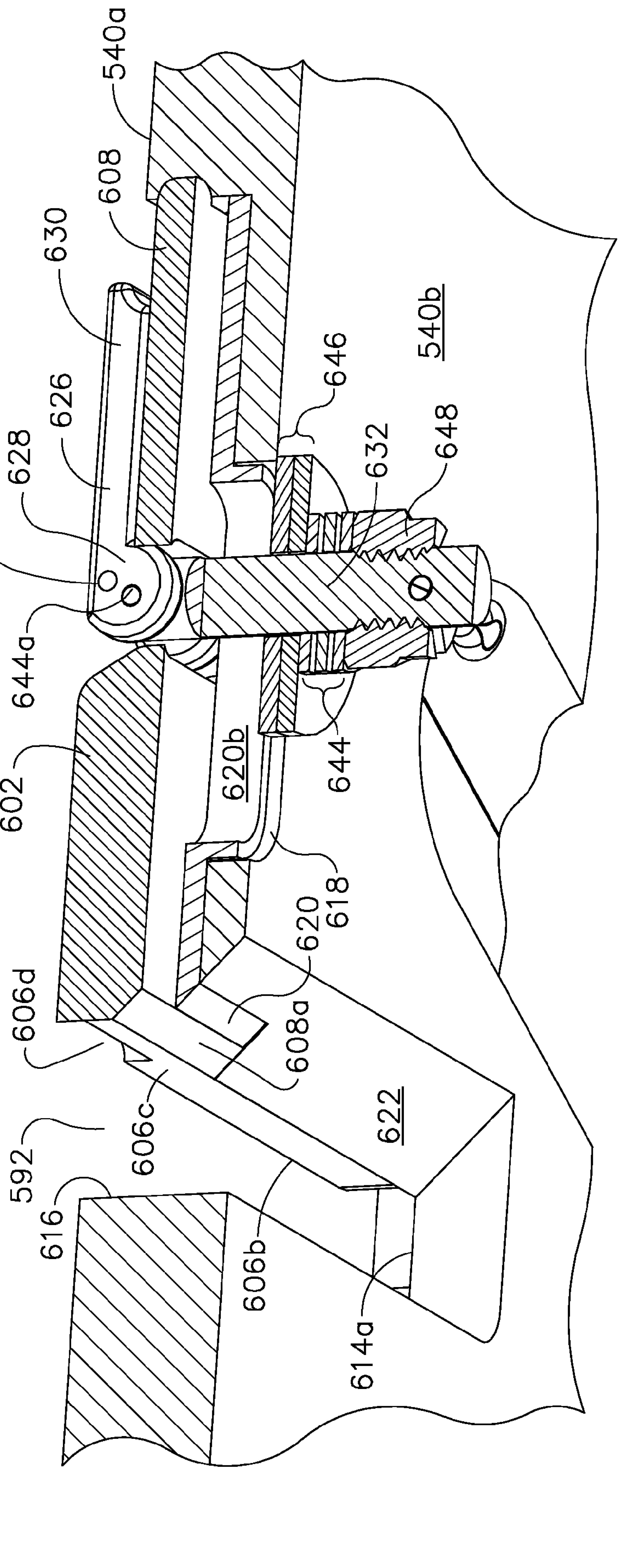
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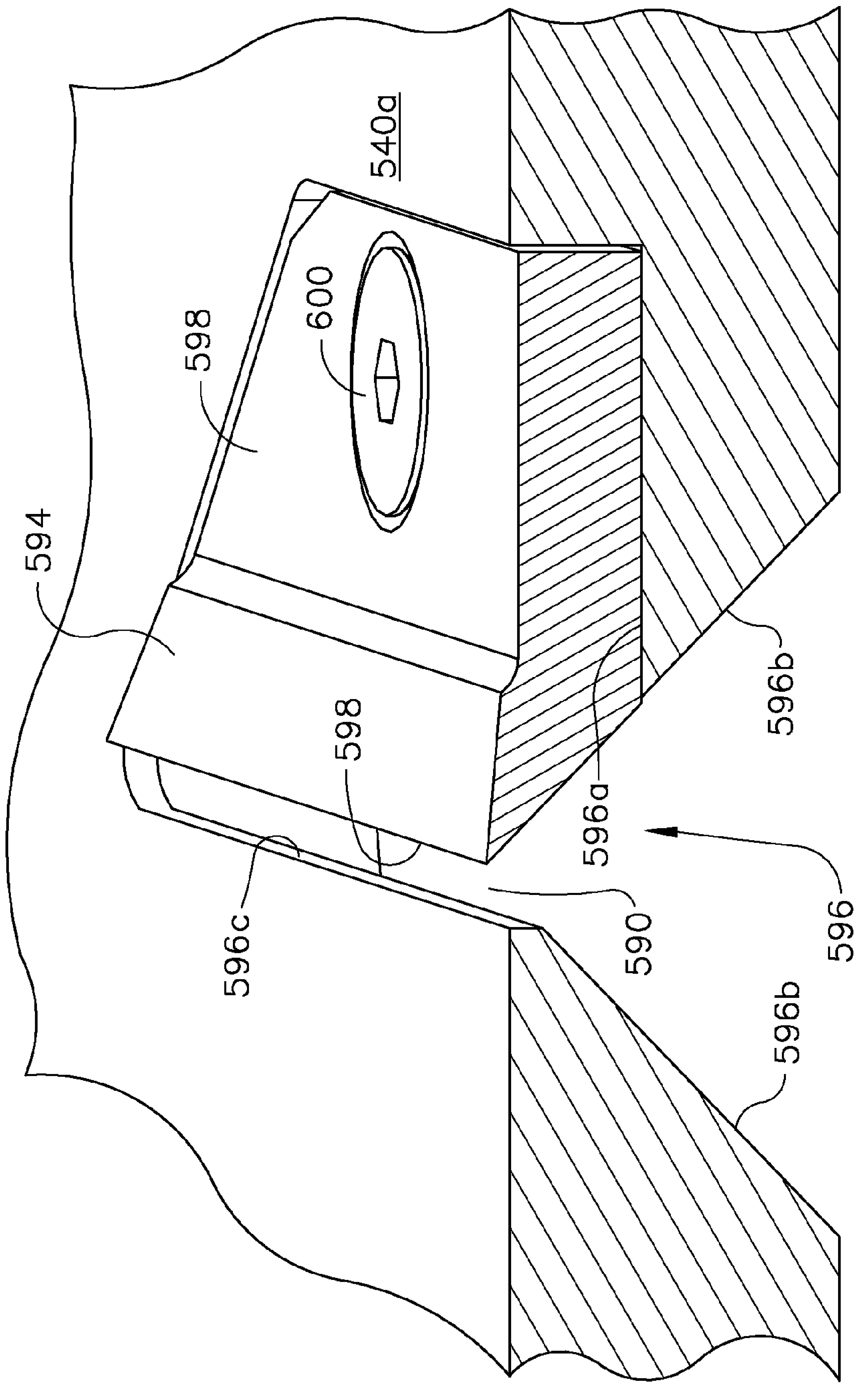
FIG. 31



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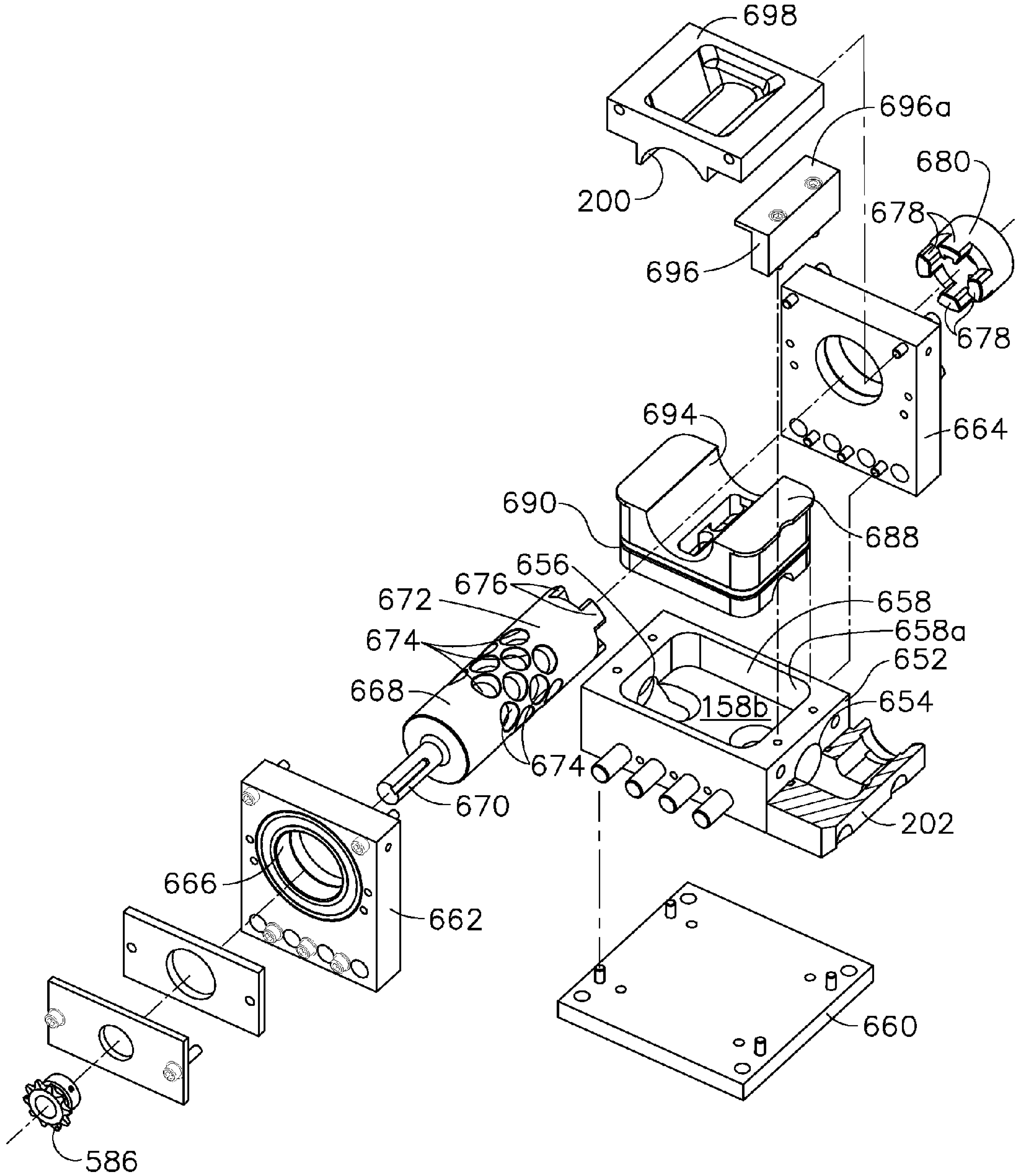
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FIG. 33

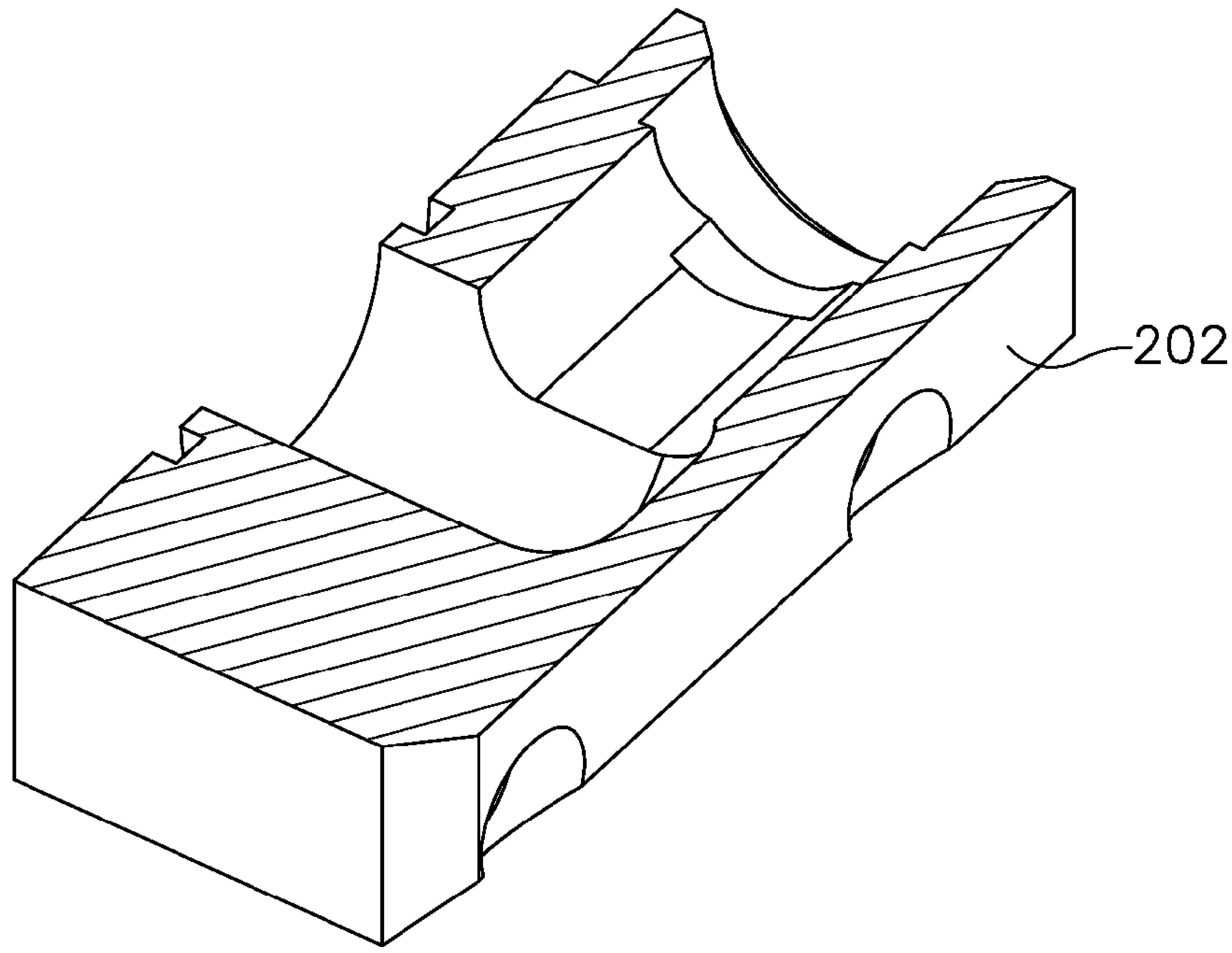


FIG. 34

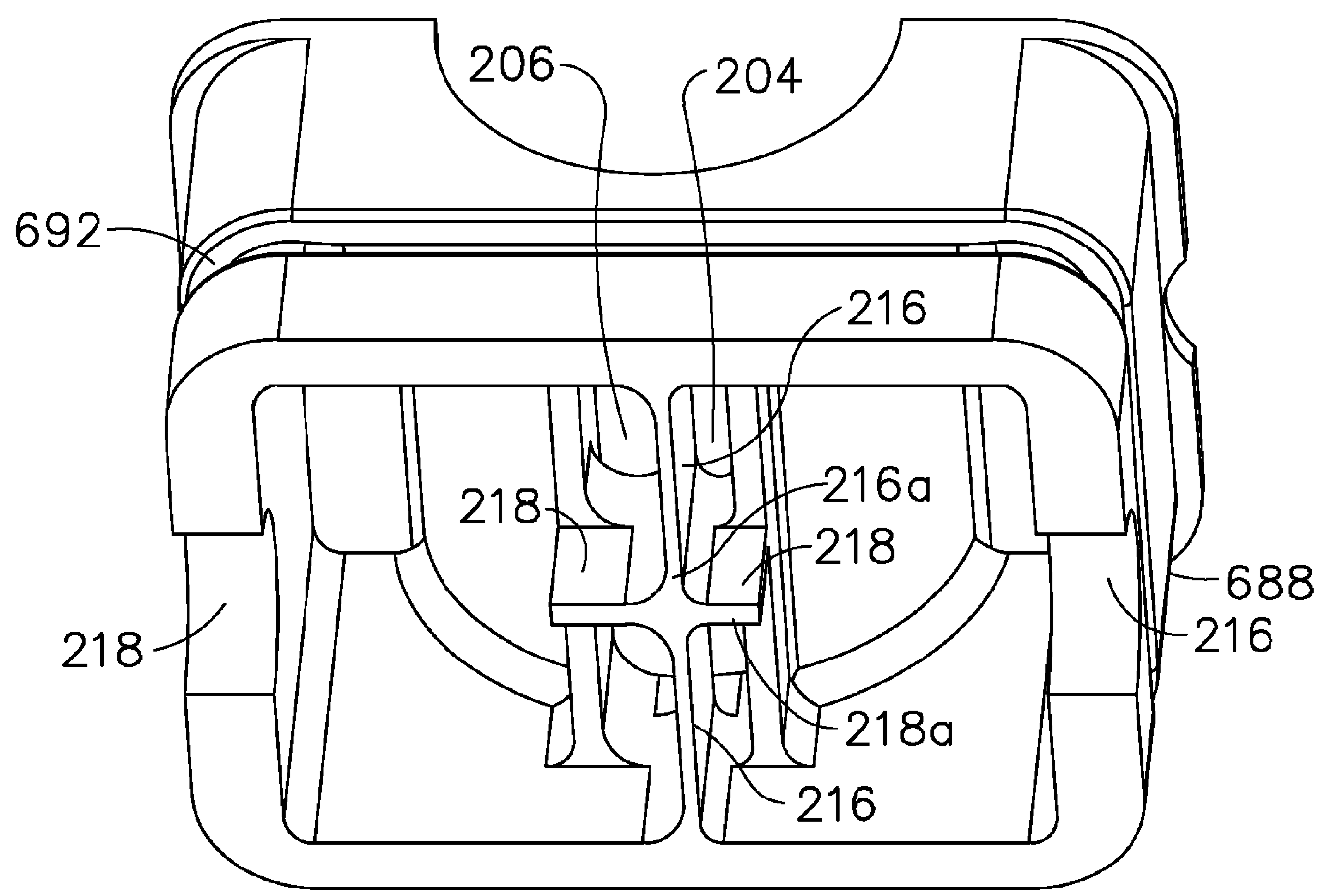


FIG. 35

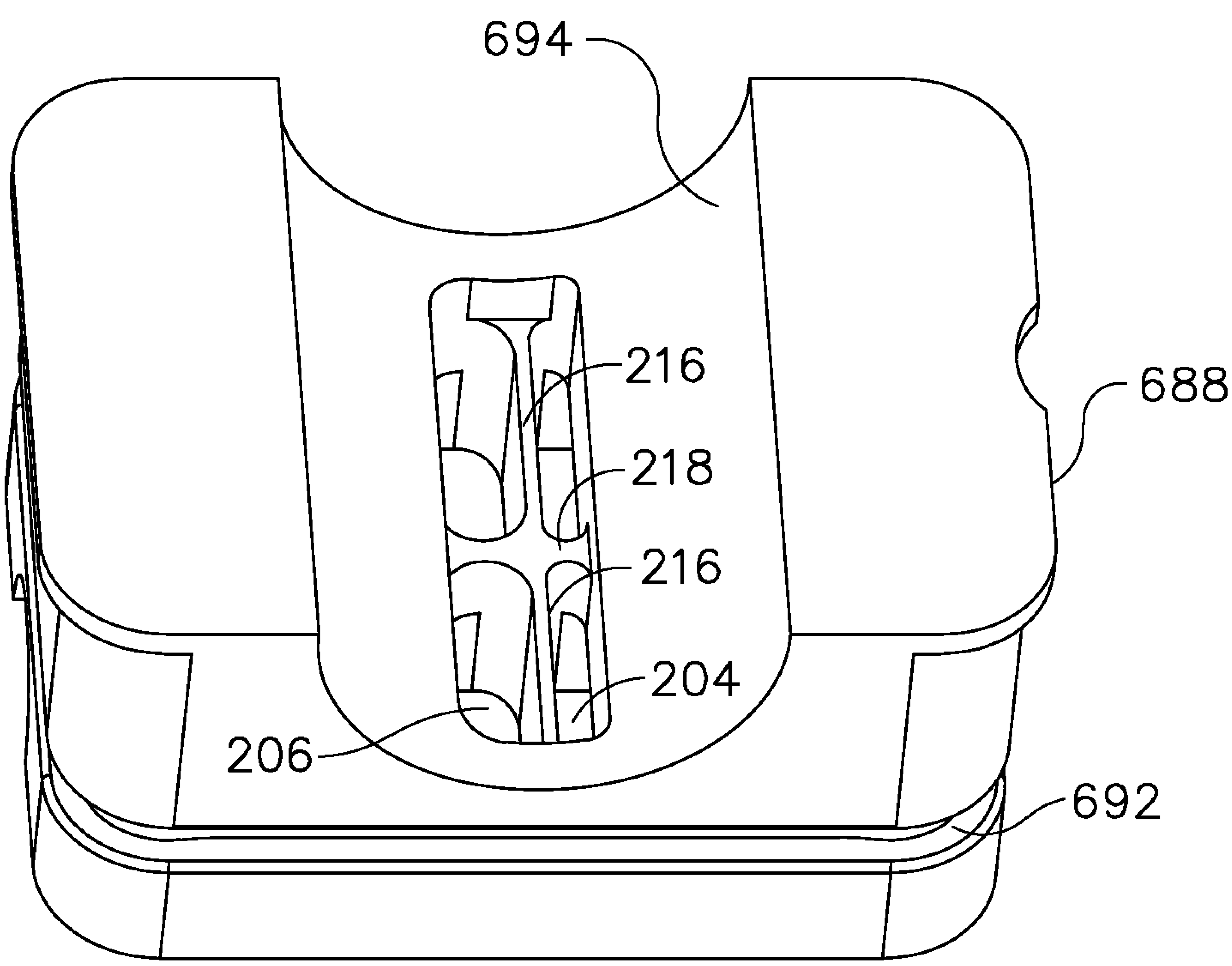
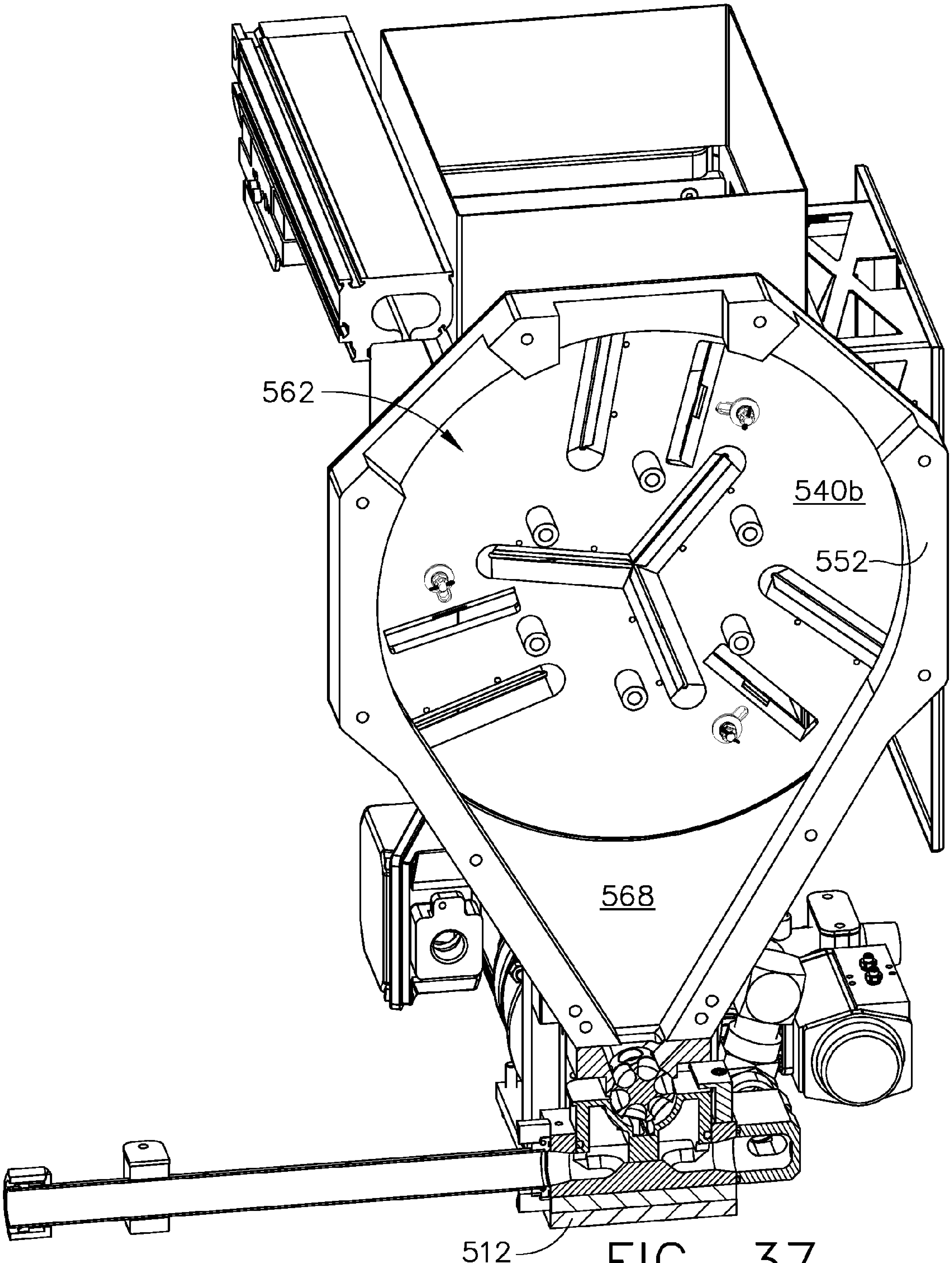


FIG. 36



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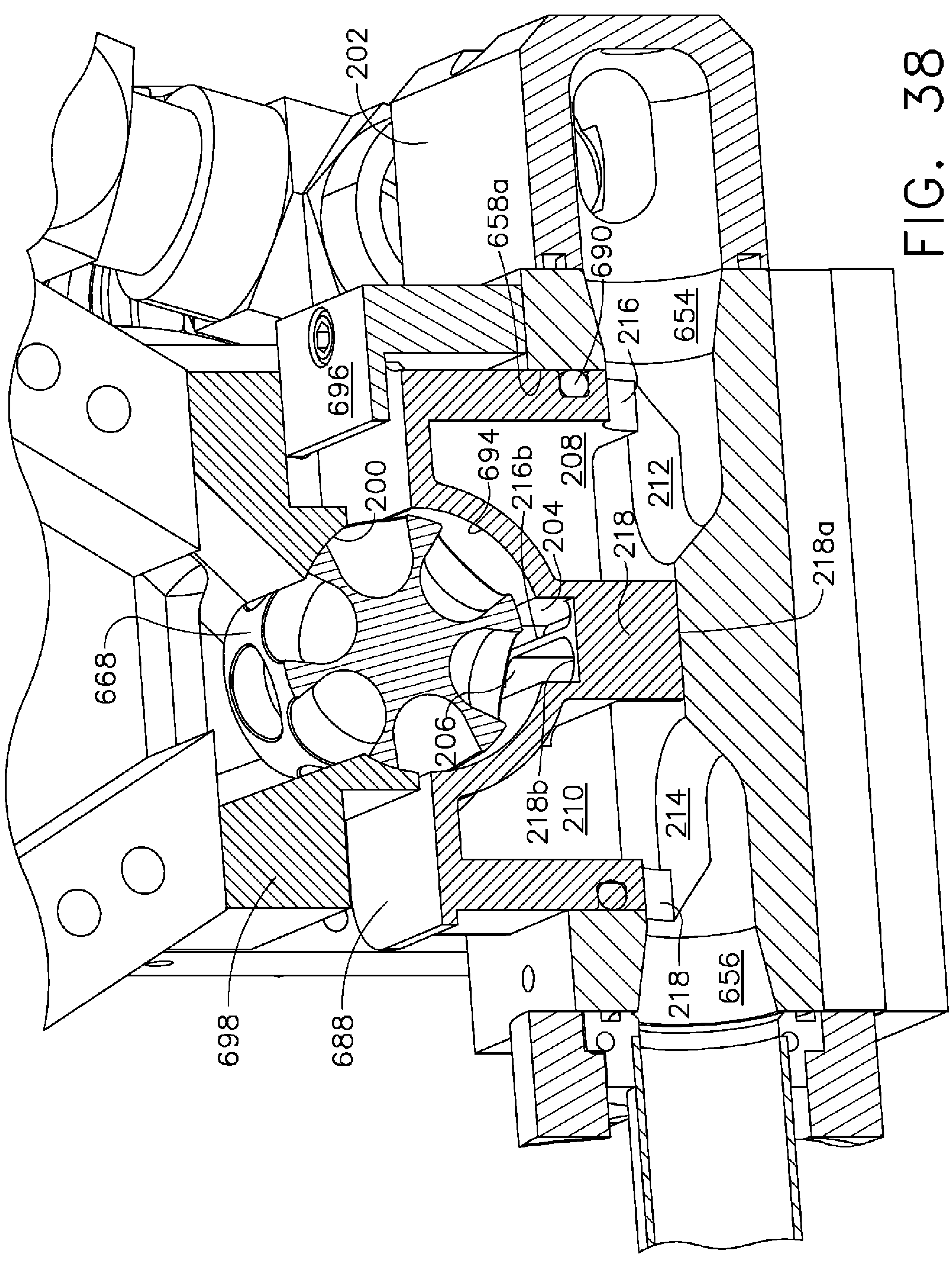
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FIG. 38

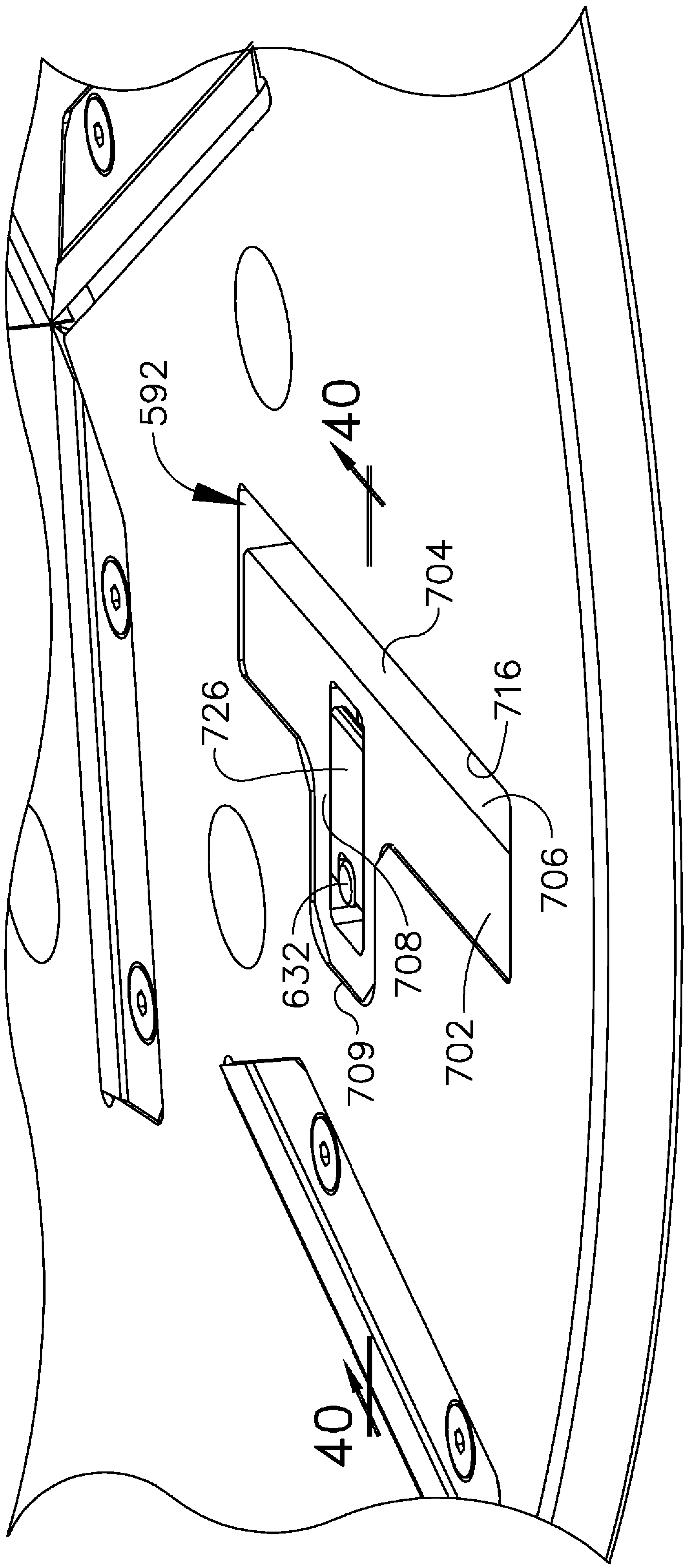

FIG. 39

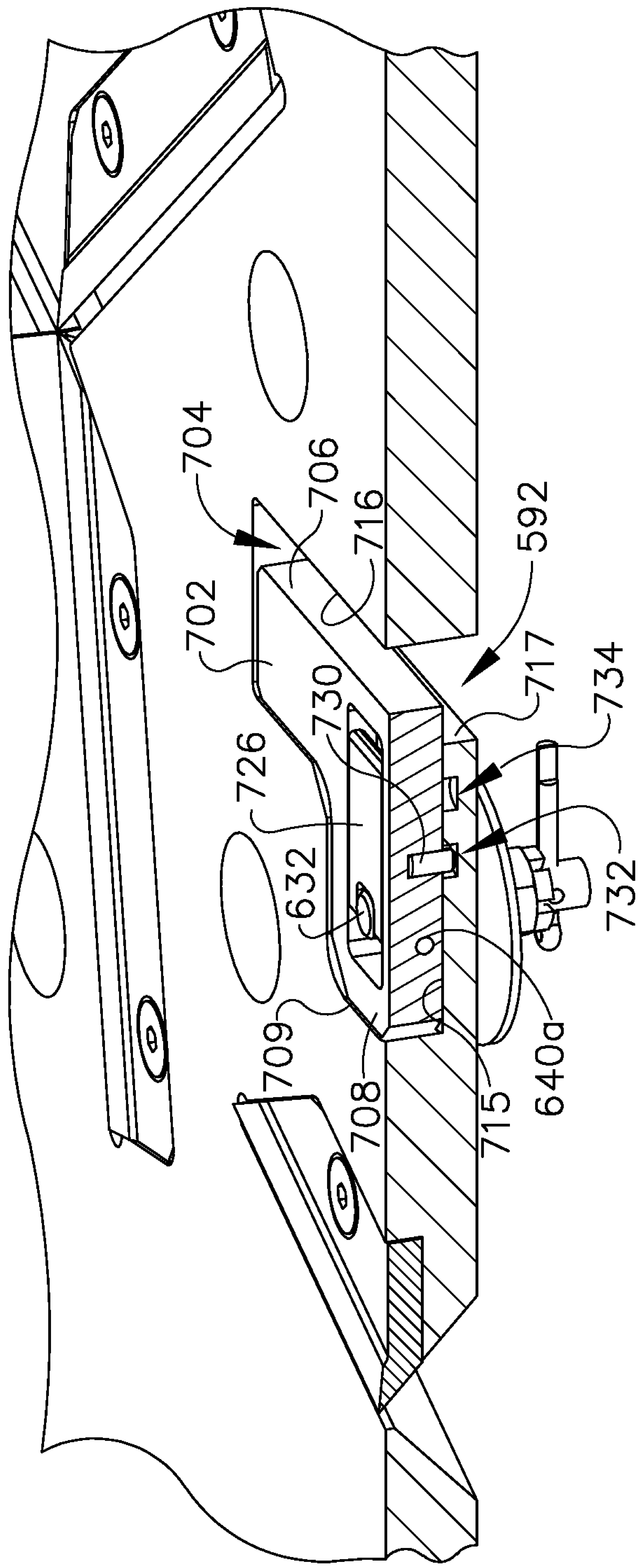

FIG. 40

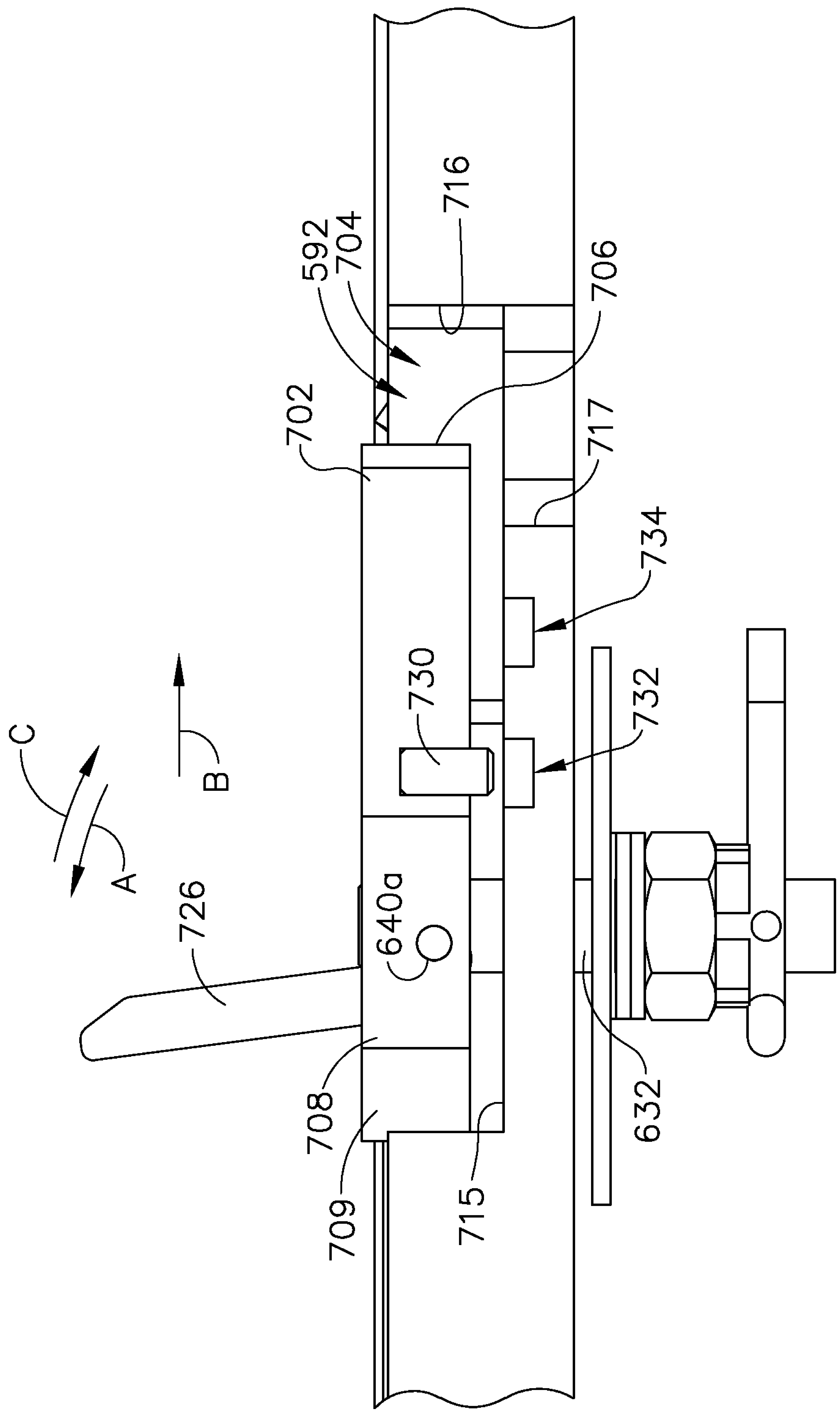

FIG. 41

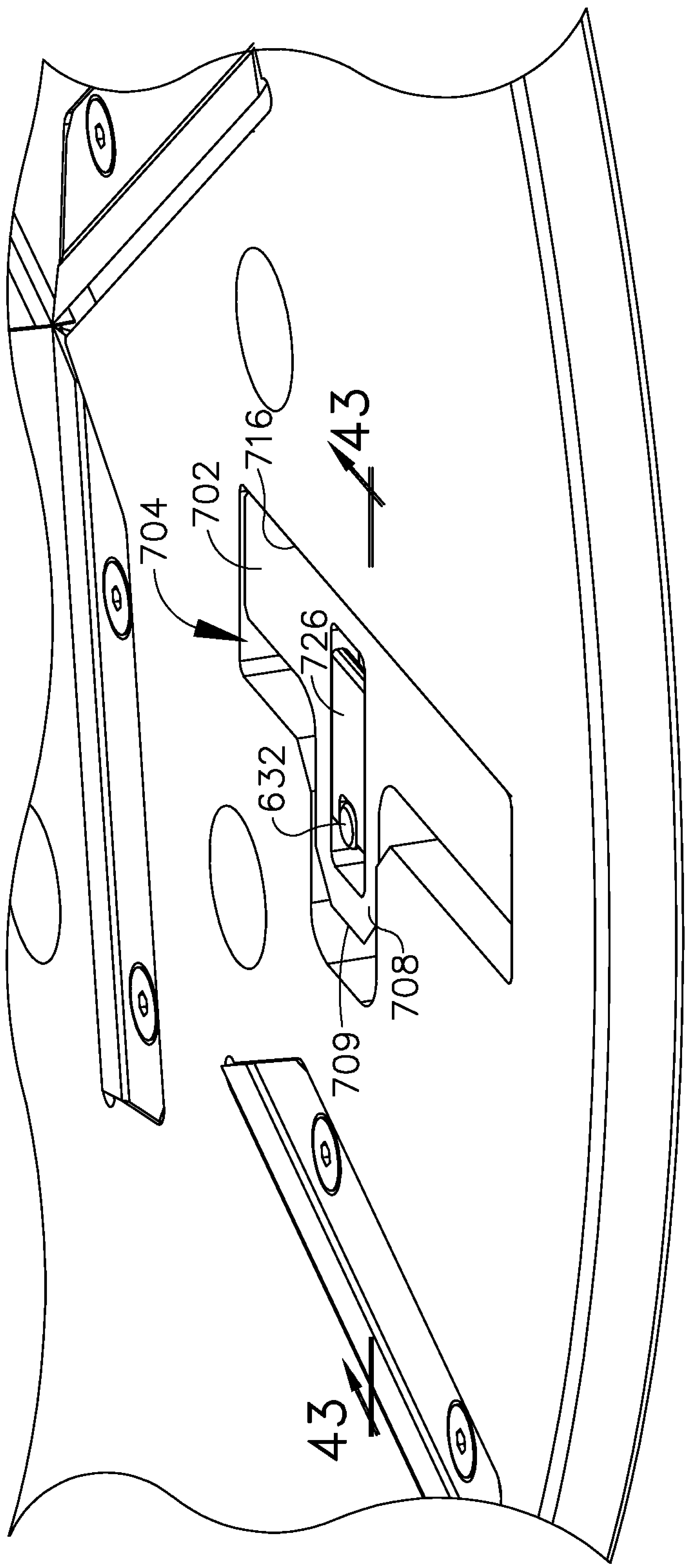

FIG. 42

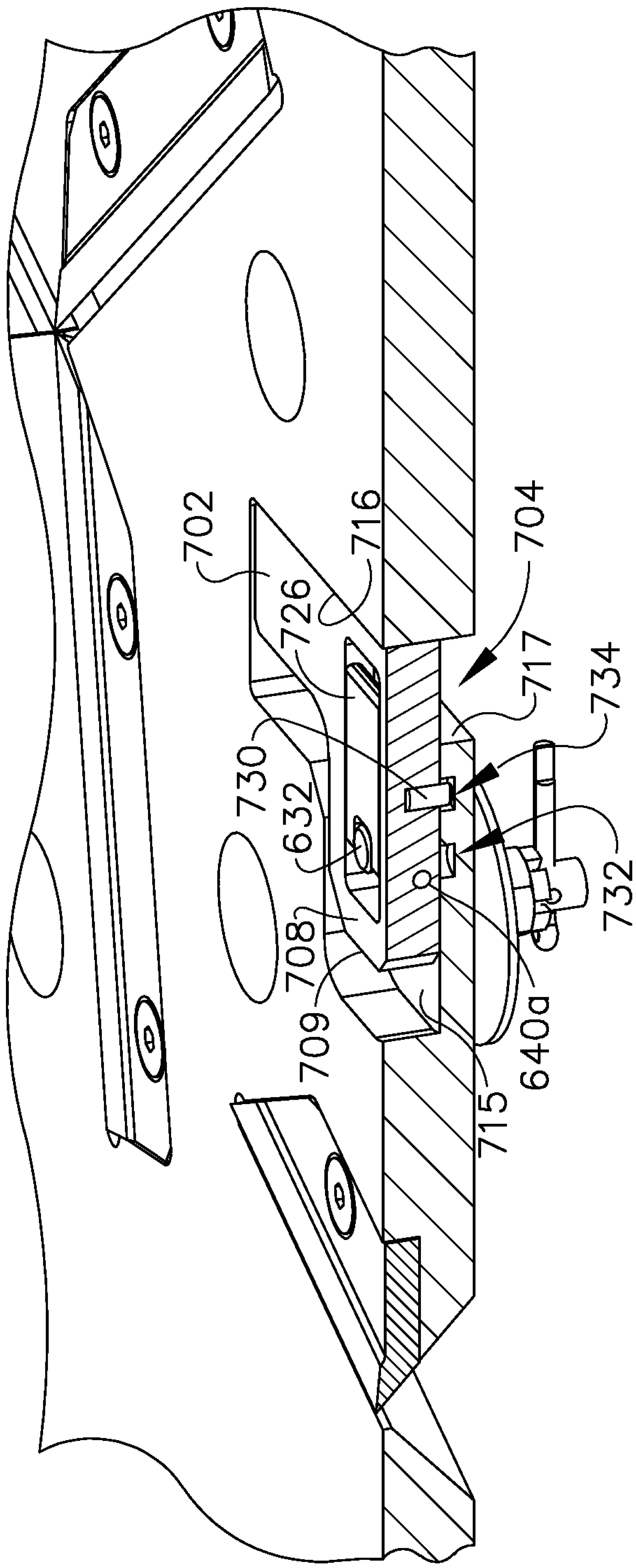

FIG. 43

APPARATUS AND METHOD FOR HIGH FLOW PARTICLE BLASTING WITHOUT PARTICLE STORAGE

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Patent App. No. 61/608,639, filed Mar. 8, 2012 and U.S. patent App. No. 61/594,347, filed Feb. 2, 2012, the disclosures of which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD

The present invention relates generally to particle blasting using cryogenic material, and is particularly directed to a method and device involving blasting with carbon dioxide blast media, such as pellets or particles, which are delivered entrained in a high flow of transport gas with substantially no storage of the carbon dioxide media.

BACKGROUND OF THE INVENTION

Carbon dioxide blasting systems are well known, and along with various associated component parts, are shown in U.S. Pat. Nos. 4,744,181, 4,843,770, 4,947,592, 5,018,667, 5,050,805, 5,071,289, 5,109,636, 5,188,151, 5,203,794, 5,249,426, 5,288,028, 5,301,509, 5,473,903, 5,520,572, 5,571,335, 5,660,580, 5,795,214, 6,024,304, 6,042,458, 6,346,035, 6,447,377, 6,695,679, 6,695,685, and 6,824,450, all of which are incorporated herein by reference. Additionally, U.S. patent application Ser. No. 11/344,583, filed Jan. 31, 2006, for PARTICLE BLAST CLEANING APPARATUS WITH PRESSURIZED CONTAINER, U.S. patent application Ser. No. 11/853,194, filed Sep. 11, 2007, for PARTICLE BLAST SYSTEM WITH SYNCHRONIZED FEEDER AND PARTICLE GENERATOR, U.S. patent application Ser. No. 12/121,356, filed May 15, 2008, for PARTICLE BLASTING METHOD AND APPARATUS THEREFOR, U.S. patent application Ser. No. 12/348,645, filed Jan. 5, 2009, for BLAST NOZZLE WITH BLAST MEDIA FRAGMENTER, U.S. Patent Provisional Application Ser. No. 61/394,688 filed Oct. 19, 2010, for METHOD AND APPARATUS FOR FORMING CARBON DIOXIDE PARTICLES INTO BLOCKS, and U.S. Patent Provisional Application Ser. No. 61/487,837 filed May 19, 2011, for METHOD AND APPARATUS FOR FORMING CARBON DIOXIDE PARTICLES, are hereby incorporated by reference.

In a particle blast system, typically, particles, also known as blast media, are ejected by a particle acceleration device, generally referred to as a blast nozzle, and directed toward a workpiece or other target (also referred to herein as an article). Particles may be introduced into a transport gas flow through a feeder, such as is disclosed in U.S. Pat. No. 6,726,549, which is incorporated herein by reference, and transported by the transport gas, entrained therein, from the feeder to the blast nozzle through a single hose (known as a one hose system). It is also known to introduce particles into the high pressure gas at the blast nozzle, the blast nozzle being configured to combine the particle flow arriving entrained in a low volume gas flow through a first hose with high pressure gas arriving in a second hose and eject the entrained flow therefrom (known as a two hose system).

Various sizes are known for carbon dioxide blast media, such as pellets and granules, the selection of which is made in dependence on the blasting needs. Pellets may be formed

by extruding carbon dioxide snow through a die plate. Pellet diameters come in various sizes, for example ranging from 3 mm to 12 mm. Granules may be formed by any suitable process, such as by use of the apparatus for generating carbon dioxide granules from a block, referred to as a shaver, as is disclosed in U.S. Pat. No. 5,520,572, which is incorporated herein by reference, in which a working edge, such as a knife edge, is urged against and moved across a block of carbon dioxide. As shown in the '572 patent, the granules so generated are fed directly into the low volume gas flow, such as by Venturi induction as shown in FIG. 1 of the '572 patent, transported by the first hose to the blast nozzle 102 ('572, FIG. 6) where it is combined with the high pressure gas and directed toward a workpiece.

Unwanted sublimation of the carbon dioxide blast media occurs prior to the media reaching the workpiece whenever the environmental conditions allow. Sublimation of granules can be a significant problem, due at least in part to the very small mass of each individual granule relative to its volume and surface area. For example, the '572 patent teaches to deliver the granules, generated by shaving a dry ice block, directly into the first hose of the two hose system with substantially no storage of the granules to be transported to be combined with the high pressure gas.

Until the present invention, due to sublimation, systems utilizing granules were limited to low flow apparatuses. Double hose and single hose granule systems were known, but high flow systems were not. Two hose systems using granular blast media were typically limited to low flow, with a maximum hose (for transporting granules) internal diameter of ¾" and maximum length of 50 feet. Previously, persons of greater than ordinary skill in the art designed such systems to avoid high volume gas flow based on the conclusion that the sublimation rate of granules was proportional to the volume of the flow of gas in which the granules were entrained, leading to prior art systems maintaining low flow through small hose diameters for hoses. Attempts at using large diameter hoses in single hose systems resulted in systems with sublimation rates that required granular media flow rates of 10 to 20 lbs per minute just to equal the results of the two hose systems delivering 5 lbs per minute. Such result reinforced the continued use of smaller hose diameters.

The present inventors have overcome the problems unsolved by such persons of more than ordinary skill in the art, and successfully configured a single hose granular blast media system capable of delivering high flow, based on their determination that the sublimation problem was not the result of the volume of the gas flow that entrained the granules, but rather was the result of the velocity of the gas flow in which the particles were entrained. The inventors have determined that it is the difference between the speed of the gas flow and the speed of the granules that results in sublimation: The greater the difference the greater the sublimation. Applying the inventors' discovery to the prior art attempts at single hose granular blast media systems, it is now to be understood that the increase in sublimation that accompanied use of a larger cross sectional area hose (i.e., the larger diameter hose), which was misinterpreted by those of more than ordinary skill in the art as resulting from increased flow volume, was the result of increased gas velocity resulting from use of nozzles which that increased the gas speed in the hose (instead of decreasing gas speed which, with increased cross sectional area, would be expected to decrease speed). However, the inventors' present invention overcomes the misunderstandings, misinterpretations and shortcomings of the prior art by providing a single hose granular blast media system with high flow configured to maintain the speed differential between the transport gas and the entrained granules low enough to keep sublimation rates low enough to be functionally acceptable.

Although the present invention will be described herein in connection with a particle feeder for use with carbon dioxide blasting, it will be understood that the present invention is not limited in use or application to carbon dioxide blasting. The teachings of the present invention may be used in applications using particles of any sublimeable and/or cryogenic material.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention, and, together with the general description of the invention given above, and the detailed description of the embodiments given below, serve to explain the principles of the present invention.

FIG. **1** is a perspective view of a particle blast apparatus constructed in accordance with teachings of the present invention.

FIG. **2** is perspective view of the particle blast apparatus of FIG. **1**, with the covers omitted.

FIG. **3** is a perspective view from the upper left front illustrating the particle generator and feeder assembly of the particle blast apparatus of FIG. **1**.

FIG. **4** is a perspective view from the lower right front illustrating the particle generator and feeder assembly of the particle blast apparatus of FIG. **1**.

FIG. **5** is a side cross-sectional view taken along the midline of the particle generator and feeder assembly of the particle blast apparatus of FIG. **1**.

FIG. **6** is front cross-sectional view taken along the midline of the particle generator and feeder assembly of the particle blast apparatus of FIG. **1**.

FIG. **7** is a perspective view of the rotatable carrier and housing of the particle generator of the particle blast apparatus of FIG. **1**.

FIG. **8** is an exploded view of the rotatable carrier of FIG. **7**.

FIG. **9** is a perspective cross-sectional view of a blade and adjustable slide of the rotatable carrier of FIG. **7**.

FIGS. **10**A, **10**B and **10**C are side, perspective and end views of a blade of the rotatable carrier of FIG. **7**.

FIG. **11** is a perspective view of the inner adjustable slide of the rotatable carrier of FIG. **7**.

FIG. **12** is a perspective view of the outer adjustable slide of the rotatable carrier of FIG. **7**.

FIG. **13** is an exploded perspective view of the feeder assembly of the particle blast apparatus of FIG. **1**.

FIG. **14**A is a perspective view of the lower seal of the feeder assembly of FIG. **13**.

FIG. **14**B is a top view of the lower seal of the feeder assembly of FIG. **13**.

FIG. **15** is a cross-sectional view of the feeder assembly of the particle blast apparatus of FIG. **1**.

FIG. **16** is a perspective view from the left front of a particle blast apparatus constructed in accordance with teachings of the present invention.

FIG. **17** is a perspective view of the particle blast apparatus of FIG. **16** from the left rear.

FIG. **18** is a perspective view from the left front illustrating the supply bin of the particle blast apparatus of FIG. **16**.

FIG. **19** is a perspective view similar to FIG. **18**, with the door in the lower position.

FIG. **20** is an perspective view similar to FIG. **5** with the linear actuator, pressure plate and rear cover exploded from the rest of the particle generator and feeder assembly.

FIG. **21** is perspective view from the right front illustrating the particle generator and feeder assembly with the door omitted.

FIG. **22** is a cross-sectional view taken along line **22-22** of FIG. **21**.

FIG. **23** is an exploded view of the driven element and the rotatable carrier.

FIG. **24** is a plan view of the outer surface of the rotatable carrier of the particle generator of the particle blast apparatus of FIG. **16**.

FIG. **25** a plan view of the inner surface of the rotatable carrier of the particle generator of the particle blast apparatus of FIG. **16**.

FIG. **26** is a perspective view of the rotatable carrier in partial cross section.

FIG. **27** is a perspective view of the rotatable carrier in partial cross section.

FIG. **28** is an exploded view illustrating the rotatable carrier, working edges and slides.

FIG. **29** is an exploded view illustrating a slide of the rotatable carrier.

FIG. **30** is a cross-sectional view taken along line **30-30** of FIG. **25**.

FIG. **31** is a cross-sectional perspective view similar to FIG. **30** illustrating the over center adjustment mechanism of the adjustable slide of the rotatable carrier.

FIG. **32** is a fragmentary perspective view of a working edge of the rotatable carrier and a cross-sectional view taken along line **32-32** of FIG. **25**.

FIG. **33** is an exploded perspective view of the feeder assembly of the particle blast apparatus of FIG. **16**.

FIG. **34** is a cross-sectional perspective of the inlet fitting which attaches to the feeder block shown in FIG. **33**.

FIG. **35** is a bottom perspective view of the lower seal of the feeder assembly of FIG. **33**.

FIG. **36** is a top view of the lower seal of the feeder assembly of FIG. **33**.

FIG. **37** is a perspective view of the particle generator and feeder assembly taken from the left with the feeder assembly shown in cross section.

FIG. **38** is a cross-sectional perspective view of the feeder assembly of the particle blast apparatus of FIG. **16**.

FIG. **39** is a fragmentary perspective view of an alternative movable insert received in an rotatable carrier disposed in an open position;

FIG. **40** is a fragmentary cross-sectional perspective view taken along line **40-40** of FIG. **39**;

FIG. **41** is a fragmentary cross-sectional side view of the insert taken along line **40-40** of FIG. **39** with the lever of the insert in a rotated position that permits the adjustment of the insert between open and closed positions;

FIG. **42** is a fragmentary perspective view of the insert of FIG. **39** in a closed position; and

FIG. **43** is a cross-sectional view taken along line **43-43** of FIG. **42**.

Reference will now be made in detail to an embodiment of the invention, an example of which is illustrated in the accompanying drawings.

DESCRIPTION

In the following description, like reference characters designate like or corresponding parts throughout the several views. Also, in the following description, it is to be understood that terms such as front, back, inside, outside, and the like are words of convenience and are not to be construed as limiting terms. Terminology used in this patent is not meant to be limiting insofar as devices described herein, or portions thereof, may be attached or utilized in other orientations. Referring in more detail to the drawings, an embodiment of the invention will now be described.

Double Motor Embodiment

FIGS. **1** and **2** show perspective views of a particle blast apparatus constructed in accordance with teachings of the present invention. Particle blast apparatus, generally indicated at **2**, includes frame **4** which carries and supports the individual components of the blaster, as will be described below. Control panel **6** is located at the front of particle blast apparatus **2** to control the device through a series of valves, switches, and timers. The valves, switches, timers, and controls that can be pneumatic, electric, or any combination thereof.

Referring to FIG. **3**, there is shown a perspective view of particle generator, generally indicated at **8**, duct **10** and feeder assembly **12**. Particle generator **8** is disposed adjacent storage bin **14**. Bin **14** is configured to receive a block of solid carbon dioxide, such as a standard size commercially available block of dry ice, e.g., 10"×10"×12", or to receive preformed pellets. Pressure plate **16** is longitudinally movable within bin **14**, toward and away from particle generator **8**. Pressure plate **16** may, as depicted in FIG. **3**, include lining **18** made of a material suitable for contacting the solid material disposed in bin **14**, such as UHMW plastic. Pressure plate **16** is configured to urge any material, whether a block or a plurality of individual pellets, disposed within bin **14**, toward particle generator **8** so as to cause such material to remain in contact with particle generator **8** with sufficient force for particle generator to generate particles for introduction into the transport gas flow. Pressure plate **16** may be resiliently biased toward particle generator **8** and/or may be connected to actuator **19** to move pressure plate **16** toward and away from particle generator **8**. In the embodiment depicted, actuator **19** is a linear actuator and includes carriage **19***a* which is connected to pressure plate **16** by arm **19***b* (see FIG. **5**) extending from carriage. Spaced apart sides **20** of bin **14** are made of any suitable material, preferably which resists the material disposed within bin **14** from sticking to sides **20**. Hinged lid **22** overlies bin **14** to facilitate filling bin **14** with material, such as dry ice. Additionally, apparatus **2** includes rear door **23** which may be opened by pivoting about a hinge, horizontal in the embodiment depicted. Pressure plate **16** may be moved out of the way to allow solid material, such a block, to be loaded into storage bin **14** from the rear.

Referring also to FIGS. **5-8**, particle generator **8** includes housing **24** to which cover **26** is attached to out facing surface **24***a* of housing **24**. Particle generator **8** includes rotatable carrier **28** which carries one or more working edges **30** and respective slides **32**. Carrier **28** moves relative to bin **14** with the material disposed in bin **14** being urged against inner surface **28***b* of carrier **28**. Carrier **28** is connected to rotor **34** by a plurality of fasteners **36**, with a plurality of spacers **38** which establish space between surface **28***a* of carrier **28** and rotor **34** through which the generated particles may fall. In the embodiment depicted, rotor **34** has a plurality of holes **34***a* in order to reduce the weight of rotor **34**. Rotor **34** also includes hub **34***b* which carries the inner races of bearings **40** that rotatably support rotor **34**. The outer races of bearings **40** are supported by frame **42**, which is in turn supported by housing **24**. Thus, through bearings **40** and hub **34***b,* rotor **34** is rotably supported by frame **42**.

Hub **34***b* also carries driven element **44**, which is non-rotatably fixed to hub **34***b*. Motor **46** is carried by apparatus **2**, with drive element **48** secured to the output of motor **46**. Belt **50** engages drive element **48** and driven element **44** to provide the rotation of hub **34** and thereby rotate carrier **28**.

Housing **24** is secured to bin **14**, with inner surface **24***b* abutting bin **14**. With cover **26** in place (not illustrated in FIG. **5**), collector chamber **52** is defined such that particles passing through openings **54** of rotatable carrier **28** flow into and through collector chamber **52**. Particles generated above hub **34** can fall though the space between hub **34** and carrier **28** created by spacers **38**. Particles fall through collector chamber **52** into duct **10** passing therethrough and out duct exit **10***a* directly to feeder assembly **12**. With cover **10***b* in place, duct **10** defines internal passageway **10***c* that places collector chamber **52** in fluid communication with feeder assembly feeder **12**.

Referring to FIGS. **7-9**, rotatable carrier **28** includes a plurality of respective openings **54** defined between respective pairs of spaced working edges **30** and slides **32***a*, **32***b*. Pairs of working edges **30** and slides **32***a* are disposed in a first plurality of respective inner recesses **56***a*, **56***b* formed at the inner portion of rotatable carrier **28**, and pairs of working edges **30** and slides **32***b* in a second plurality of respective outer recesses **58***a,* **58***b*. As seen in FIGS. **9**, **10**A, **10**B and **10**C, working edge **30** includes elongated raised cutting edge **30***a* which is disposed facing slides **32***b*. Working edge **30** includes a plurality of openings **30***b* into which fasteners **60** are disposed to secure working edge **30** in recess **58***a*. Any suitable opening **30***b* and fastener **60** may be used, which in the depicted embodiment are closely confirming to each other so as to hold working edge **30** in a single location (subject to tolerance). Referring also to FIG. **12**, outer slide **32***b* includes elongated surface **32***c* which is disposed opposite cutting edge **30***a*. Slide **32***b* includes a plurality of openings into which fasteners **60** as disposed to secure slide **32***b* in recess **58***b*. As seen in FIG. **11**, slide **32***a* has a similar construction as slide **32***b*, it being noted that the differences between the inner and outer slides arises from the geometry of openings **56***a*/**56***b* and **58***a*/**58***b*.

Slide **32***b* is configured to be disposed at a first position as seen in FIG. **9**, at which the width of opening **54** is at its largest, and a second position at which the width of opening **54** is at its smallest. It is within the scope of this invention for slide **32***b* to be disposed at a plurality of positions between the first and second positions, whether configured as indexed positions or infinite positions. Such range of positions is accomplished through the mount configuration, which in the embodiment depicted encompasses openings **62** being configured as elongated slots into which fasteners **60** are disposed to secure slide **32***b* positionably within outer recess **58***b*. Slide **32***a* is similarly configured to be positionable.

When slide **32***a* or **32***b* is in the first position, at which opening **54** is at its largest, larger particles may pass through the larger gap. This allows pellets to pass through opening **54** as rotatable carriage **28** is rotated, permitting pellets to be used, disposed in storage bin **14** and transported to feeder assembly **12**. Pellets being dispensed may also be reduced in size as they pass between working edges and spacers.

For blocks of solid material, slides **32***a*, **32***b* are disposed in the second position, at which opening **54** is at its smallest. Moving working edges **30** engage the block disposed in bin **14**, with the relative motion causing particles to be generated (created), whether by shaving the block. Small particles could also be generated from pellets when slides **32***a*, **32***b* are in the second position.

Referring to FIGS. **13**, **14**A and **14**B, feeder assembly **12** includes feeder block **64** in which inlet **66** and outlet **68** are formed. Feeder block **64** includes cavity **70** defined by wall **70***a* and bottom **70***b*. Feeder block **64** is secured to plate **72** which may be secured to the frame of apparatus **2**. A pair of spaced apart bearing supports **74**, **76** respectively carry axially aligned sealed bearings **78**, **80**.

Rotor **82** may be from any suitable material and is depicted as a cylinder, although various other shapes, such as frustoconical may be used. Threaded hole **82***a* is formed in the end of rotor **82**. Rotor **82** includes peripheral surface **84** in which a plurality of spaced apart pockets **86** are formed. In the embodiment shown, there are four circumferential rows of pockets **86**, with each circumferential row having six pockets **86**. Pockets **86** are also aligned in axial rows, with each axial row having two pockets **86**. The axial and circumferential rows are arranged such that the axial and circumferential widths of pockets **86** overlap, but do not intersect, each other.

In this embodiment, rotor **86** is rotatably carried by bearings **78**, **80**, for rotation by motor **88** (see FIGS. **2-4**). Drive member **90** is connected to rotor **86** and is driven via drive element **92**, which is driven by drive member **94** carried by motor **88**. Thrust bearing plate **96** and retaining plate **98** are disposed at one end. Thrust bearing plate **96** may be made of any suitable material, such as UHMW plastic. Rotor hub **82***b* extends through opening **100** of thrust bearing plate **96** and retaining plate **98**, engaging retainer bearing disc **102** which is backed by retainer **104** by fastener **106** extending therethrough, threadingly engaging threaded hole **82***a* so as to retain rotor **86**. The fit between bearings **74**, **76** and rotor **82** allows rotor **82** to be easily withdrawn from feeder assembly **12** by unscrewing fastener **106** and sliding rotor out through bearing **76**.

Lower seal pad **108** is disposed partially in cavity **70**, with seal **110**, located in groove **112**, sealingly engaging groove **112** and wall **70***a*. Lower seal pad **108** includes surface **114** which, when assembled, contacts peripheral surface **84** of rotor **82**, forming a seal therewith, as described below. Brackets **116** are attached to block **64** by fasteners (not shown), and have portions **116***a* which overly the upper surface of lower seal **108** so as to retain lower seal **108** to block **64**. As used herein, "pad" is not used as limiting: "Seal pad" refers to any component which forms a seal.

Upper seal pad **118** includes surface **120** which, when assembled, contacts peripheral surface **84** of rotor **82**. Fasteners **122** are disposed through holes in upper seal pad **118** to hold it in place, without significant force being exerted by surface **120** on rotor **82**.

Upper seal pad **118** and lower seal pad **108** may be made of any suitable material, such as a UHMW material. The ends of surfaces **114** and **120** adjacent bearing **80** may be chamfered to allow easier insertion of rotor **82**

Referring also to FIG. **15**, lower pad seal **108** is shown disposed in cavity **70**, with seal **110** engaging wall **70***a*, and upper pad seal **118** overlying but not engaging lower pad seal **108**, surface **120** engaging rotor **82**. Surface **114** includes two openings **124** which are in fluid communication with inlet **66** through upstream chamber **128**, and two openings **126** which are in fluid communication with outlet **68** through downstream chamber **130**. It is noted that although two openings **124** and two openings **126** are present in the illustrated embodiment, the number of openings **124** and openings **126** may vary, depending on the design of feeder assembly **12**. For example, a single opening may be used for each. Additionally, more than two openings may be used for each.

Feeder assembly **12** has a transport gas flowpath from inlet **66** to outlet **68**. In the depicted embodiment, passageways **132** and **134** are formed in feeder block **64**. Lower seal pad **108** includes recess **136**, which is aligned with inlet **66** and together with passageway **132**, places upstream chamber **128** in fluid communication with inlet **66**. Lower seal pad **108** also includes recess **138**, which is aligned with outlet **68** and together with passageway **134**, places downstream chamber **130** in fluid communication with outlet **68**.

Upstream chamber **128** is separated from downstream chamber **130** by wall **140** which extends transversely across lower seal pad **108**. Lower surface **140***a* of wall **140** seals against bottom **70***b* of cavity **70**, keeping upstream chamber **128** separate from downstream chamber **130**. Wall **142** is disposed perpendicular to wall **140**, with lower surface **140***a* engaging bottom **70***b*.

As illustrated, in the depicted embodiment, inlet **66** in fluid communication with outlet **68** substantially only through individual pockets **86** as they are cyclically disposed by rotation of rotor **82** between a first position at which an individual pocket first spans openings **124** and **126** and a second position at which the individual pocket last spans openings **124** and **126**. This configuration directs substantially all of the transport gas entering **66** to pass through pockets **86**, which pushes the blast media out of pockets **86**, to become entrained in the transport gas flow. Turbulent flow occurs in downstream chamber **130**, promoting mixing of media with the transport gas. Such mixing of the media entrains the media in the transport gas, minimizing impacts between the media and the feeder components downstream of the pockets. The significant flow of the transport gas through each pocket **86** acts to effectively clean all media from each pocket **86**.

It is noted that there is a gap above top **140***b* of wall **140** and top **142***b* of wall **142** and peripheral surface **84** of rotor **82**. Some transport gas flows across tops **140***b* and **142***b* from upstream chamber **128** to downstream chamber **130**.

Particles generated by action of working edges **30** across a block or a plurality of pellets disposed in storage bin **14**, or particles passed through openings **54**, travel directly through collector chamber **52** and internal passageway **10***c* into feeder assembly **12**. The speeds of motor **46** and motor **88** are controlled such that the displaced volumetric rate of pockets **86** is greater than the particle capacity of rotatable carrier **28** and associated parts at maximum speed. Thus, such particles reach feeder assembly **12** without being held or stored for any appreciable time period.

Single Motor Embodiment

FIGS. **16** and **17** show perspective views of a particle blast apparatus constructed in accordance with teachings of the present invention. Particle blast apparatus, generally indicated at **521**, includes frame **541** which carries and supports the individual components, as will be described below. Control panel **561** is located at the rear of particle blast apparatus **521** for use by the user to control the particle blast apparatus through a valves, switches, and timers. The valves, switches, timers, and controls can be pneumatic, electric, or any combination thereof.

Referring to FIGS. **18-20**, there is shown a perspective view of the assembly including supply bin **581**, particle generator **510** and feeder assembly **512**. Bin **581** is configured to receive a block of solid carbon dioxide of any suitable size, particularly but not limited to standard commercially available blocks of dry ice, e.g., 10" ×10" ×12", or to receive loose particles such as preformed pellets. Loose particles may be loaded into supply bin **581** through top opening **514**, which in the embodiment depicted may include shroud **516** surrounding opening **514** and extending upwardly aligned with opening **518**, which may be selectively covered or uncovered by lid **520**. A block of solid carbon dioxide may be loaded into supply bin **8** through top opening **514**, or loaded through side opening **522**.

Movable door assembly **524** may be disposed at a first position at which side opening **522** is covered, functioning to retain solid carbon dioxide, whether loose particles or a solid block, within supply bin **581**, forming a side thereof. Movable door assembly **524** is movable to a second position at which sufficient access to side opening **522** exists to load carbon dioxide into supply bin **581**. It is noted that loose particles of carbon dioxide could be loaded through side opening **522**, with an appropriate configuration of movable door assembly **524**.

In the depicted embodiment, movable door assembly **524** includes inner door **526** which is hingedly connected to supply bin **581** to rotate about a horizontal axis from the vertical position, essentially forming a wall of supply bin **581**, to the horizontal position, forming a shelf on which a block of dry ice could be supported and then slide into supply bin **581**. Movable door assembly **524** includes outer door **528** carried by and spaced apart from inner door **526** by spacer **530** which is secured to inner door **526**. Outer door **528** may thus be aligned with the outer skin **532** of particle blast apparatus **521**. This configuration of movable door assembly **524** cooperates with the complementary shaped opening in skin **532** to accommodate the fact that outer door **528** pivots about an offset axis, not about its lower edge, thereby producing rotation and translation. Thus the lower edge of outer door **528** is lower than the pivot axis, approximately by the distance between outer door **528** and inner door **526** defined by spacer **530**, causing the lower edge of outer door **528** to move inside of outer skin **532** as movable door assembly is rotated. Of course, any suitable configuration may be used to accomplish the function of movable door assembly.

Latch **534** may be included to hold movable door assembly **524** in the vertical position. Support arms **536***a* and **536***b* extend between movable door assembly **524** and frame **541** (not seen in FIGS. **19-21**) to support movable door assembly **524** in the horizontal position. Although support arms **536***a* and **536***b* are depicted as respective folding assemblies pivoting about each member's ends, support arms **536***a* and **536***b* may have any suitable configuration, such as retractable or non-retractable cables.

The rear wall of supply bin **581** is defined by moveable pressure plate **538**, which is configured to urge any material, whether a block or a plurality of individual particles, disposed within supply bin **581**, toward rotatable carrier **540** of particle generator **510** so as to cause such material to remain in contact with rotatable carrier **540** with sufficient force for particle generator to generate particles for introduction into the transport gas flow, as described below. Pressure plate **538** may be resiliently biased toward rotatable carrier **540** and/or may be actively urged and moved there towards, and may, as depicted, include a plurality of projections **538***b*. Actuator **542** may be disposed adjacent supply bin **581**, and configured to move pressure plate **538** toward and away from rotatable carrier **540** of particle generator **510**. In the embodiment depicted, actuator **542** is a linear actuator and includes carriage **544** which is connected to pressure plate **538** by arm **546** extending from carriage **544**. Non-moving member **548** may be provided, in the embodiment depicted attached to actuator **542**.

Excluding rotatable carrier **540**, the spaced apart interior surfaces of supply bin **581** may be made of any suitable material, preferably which resists the material disposed within bin **581** from sticking to sides **520**. Inner door **526** includes liner **526***a*, and pressure plate **538** includes liner **538***a*, which may be made of UHMW plastic. Liner **538***a* as depicted includes a plurality of openings through which projections **538***b* extend. Similarly, bottom **550** may be a liner made of UHMW. Other suitable materials, such as smooth stainless steel may be used.

It is noted that the configuration of supply bin **581** is not limited to the embodiment depicted, and may have any configuration suitable to present a supply of media to particle generator **510**. For example, supply bin **581** may be configured without sides, suitable for use with a preformed block of carbon dioxide.

Referring also to FIGS. **21-23**, particle generator **510** includes housing **552** which is secured to supply bin **581**. Housing **552** includes front upper cover **554**, rear upper cover **556** and rear side covers **558** and **560**, which collectively define collector chamber **562**. Housing **552** includes lower front cover **564**, which collectively define duct **566** which defines internal passageway **568** which places collector chamber **562** in fluid communication with feeder assembly **512**. Particles passing through openings (as described below) of rotatable carrier **540** flow into and through collector chamber **562**, and into and through internal passageway **568** and to feeder assembly **512**.

Rotatable carrier **540** is movable, and in operation moves, relative to supply bin **581** with the material disposed in supply bin **581** being urged against inner surface **540***a* of rotatable carrier **540**. The rotation of rotatable carrier **540** results in the generation (or feeding) of particles into collector chamber **562**. Therefore, the rate of rotation of rotatable carrier **540** determines the rate at which particles are generated (or fed) into collector chamber **562** into internal passage way **568** and to feeder assembly **512**. Rotatable carrier **540** is connected to rotor **570** by a plurality of fasteners **574**, with a plurality of spacers **576** establishing space between surface **540***a* of rotatable carrier **540** and rotor **570** through which the generated particles may fall. In the embodiment depicted, rotor **570** has a plurality of holes **570***a* in order to reduce the weight of rotor **570**. Rotor **570** also includes hub **572** which carries the inner races of bearings **578** that rotatably support rotor **570**. The outer races of bearings **578** are supported by bearing block **580** which is secured to cover **552** by a plurality of fasteners **582**.

Hub **572** also carries driven element **584**, which is non-rotatably fixed to hub **572**. Drive element **586** drives driven element **584** through endless drive element **588**, which is configured complementarily with driven element **584** and drive element **586**. In the embodiment depicted, driven element **584** and drive element **586** are depicted as toothed elements, such as sprockets, with endless drive element **588** being a toothed belt or chain. Thus the rotation of driven element **584** is synchronized with the rotation of drive element **586**. Since the rotation of rotatable carrier **540** is synchronized with the rotation of driven element **584** (in the embodiment depicted 1:1) and since, as described below, the rotation of drive element **586** is synchronized with the rotation of the feeder rotor of feeder assembly **512**, the rate at which particles are generated is synchronized with the rotational rate of the feeder rotor.

Referring to FIGS. **24-28**, rotatable carrier **540** includes a plurality of fixed openings **590** and adjustable openings **592**. Also referring to FIG. **32**, in the embodiment depicted, a plurality of fixed inserts **594** are disposed in respective recessed openings **596**. The configuration of each recessed opening includes recessed portion **596***a* in surface **540***a* of rotatable carrier **540**, recessed slot **596***b* diverging in the direction from surface **540***a* to **540***b* of rotatable carrier **540**, and edge **596***c*. Each fixed insert **594** has working edge **598**, with fixed openings **590** being the gaps defined between edges **596***c* of recessed openings **596** and working edges **598**. Inserts **594** are secured to rotatable carrier **540** by a plurality of fasteners **600**. Working edges **598** are configured to generate particles, such as granules, through a shaving action by moving across an adjacent face of a block of carbon dioxide being urged against inner surface **540***a* of rotatable carrier **540**. In the embodiment depicted, working edges **598** are configured as knife edges extending above inner surface **540***a*. The size and amount of particles being generated by the shaving action is a function of the configuration of working edges **598** and fixed openings **590**. The rate of the relative motion between working edges **598** and the adjacent face of the dry ice block determines the rate at which particles are generated for a particular working edge/fixed opening configuration.

In the embodiment depicted, an inner plurality of fixed openings **590** extending generally radially outward from the center of rotatable carrier **540**. An outer plurality of fixed openings **590** is disposed spaced from the center of rotatable carrier **540** oriented non-radially. In the embodiment depicted, the outer plurality of fixed openings **590** appear oriented generally perpendicular to respective ones of the inner plurality of fixed openings **590**. Any suitable configuration, e.g., location and orientation, of fixed openings **590** may be used. Additionally, although not shown in these figures, fixed inserts **594** could be configured to be movable to define non-fixed openings, with working edges **598** functioning to shave.

Referring also to FIGS. **29-31**, a plurality of movable inserts **602**, also referred to herein as slides **602**, are disposed in respective recessed openings **604**. Each slide **602** has a generally T shaped configuration with arm portions **606***a* and **606***b* extending outwardly from central portion **608** generally perpendicularly therefrom. Recessed openings **604** include recessed central portion **610** and recessed arm portion **612** and **614**. Recessed arm portion **612** includes tip **612***a* and recessed arm portion **614** includes recessed tip **614***a*.

Edges **616** define a fixed boundary of openings **592**, with movable edges **606***c* of slides **602** defining the other boundary. Formed in edges **606***c* are recesses **606***d*, which provide a surface spaced apart from edges **616** when edges **606***c* are proximal edges **616**.

Recessed arm portions **612** and **614** are depicted as having the same thickness of arm portions **606***a* and **606***b*, while the overall width is greater than the width of opening **592** with the distal ends of arm portions **606***a* and **606***b* overlying tips **612***a* and **614***a* respectively, providing support therefor.

Central portion **608** is thicker than arm portions **606***a* and **606***b*, as seen at **608***a*. Recessed central portion **610** of recessed opening **604** is shaped complementarily to central portion **608** although deeper than the thickness of central portion **608**, and including elongated slot **618**. Disposed within recessed central portion **610** is complementarily shaped stem portion insert **620**, having elongated slot **620***a* defined by wall **620***b* which extends into elongated slot **618**. Insert **620** may be made of any suitable material, such as UHMW.

Opening **604** includes inclined surface **622** extending divergingly in the direction toward outer surface **540***b*.

Central portion **608** includes recess **624** configured to receive rotatable over-center lever **626**. Lever **626** includes head portion **628** and arm **630**. Head portion **628** is pivotably connected to retaining member **632** by pin **634** extending through hole **636** in head portion **628** and hole **638** depicted as disposed generally on the axis of retaining member **632**. Head portion is also pivotably connected to central portion **608** by two pins **640***a* and **640***b* extending through respective holes **642***a* and **642***b* of central portion **608** and into holes **644***a* and **644***b* of head portion **628**.

Retaining member **632** is threaded at its end distal over center lever **626** and extends through slot **618** beyond outer surface **540***b* of rotatable carrier **540**. A plurality of spring washers **644** disposed between bearing washers **646** and nut **648**. To prevent nut **648** from rotating, cotter pin **650** is used. Over center lever is thus resiliently biased in the direction from inner surface **540***a* toward outer surface **540***b* by retaining member **632**. Holes **644***a* and **644***b* are offset relative to holes **636** and **638**, producing an over-center construction. Slide **602** may be moved within recessed opening between the fully open position illustrated in FIG. **31**, whereat opening **592** is at its maximum size to the closed position with edge **616** adjacent edge **606***c*, whereat **592** is at its minimum, which is fully closed in the embodiment depicted.

In one mode, openings **592** may be set at their minimums when a block of solid carbon dioxide is disposed in supply bin **581** and working edges **598** are shaving particles from the adjacent face. In another mode, when loose particles, such as pellets, are disposed in supply bin **581**, openings **592** may be set between and up to its minimum and maximum size to meter the loose particles to feeder assembly **512**. The size of openings **592** as well as the rotational speed of rotatable carrier **540** determine the flow rate of particles. At any given rotational speed, the larger the openings **592** the higher the flow rate of particles.

Referring to FIGS. **33-38**, feeder assembly **512** includes feeder block **652** in which inlet **654** and outlet **656** are formed. Inlet **654** includes inlet fitting **202**. Feeder block **652** includes cavity **658** defined by wall **658***a* and bottom **658***b*. Feeder block **652** is secured to plate **660** which may be secured to the frame of apparatus **521**. A pair of spaced apart supports **662** and **664** are secured to feeder block **652**. Sealed bearing **666** is carried by support **662**.

Rotor **668** may be from any suitable material and is depicted as a cylinder, although various other shapes, such as frustoconical may be used. Shaft **670** extends from rotor **668**, with drive element **586** disposed thereon. Rotor **668** includes peripheral surface **672** in which a plurality of spaced apart pockets **674** are formed. In the embodiment shown, there are four circumferential rows of pockets **674**, with each circumferential row having six pockets **674**. Pockets **674** are also aligned in axial rows, with each axial row having two pockets **674**. The axial and circumferential rows are arranged such that the axial and circumferential widths of pockets **674** overlap, but do not intersect, each other.

In this embodiment, rotor **668** includes legs **676** which are engaged by legs **678** of coupling **680**. Coupling **680** may be secured to motor **682** such that rotor **668** may be driven by motor **682**, thereby driving drive element **586**, which in turn drives driven element **584** through endless drive element **588**. In this configuration, when properly aligned, rotor **668** does not experience significant axial loading. Retaining plates **684** and **686** are disposed at one end of rotor **668**, and may be made of any suitable material, such as UHMW plastic. The fit between bearing **666** and rotor **668** allows rotor **668** to be easily withdrawn from feeder assembly **512** by removing retaining plates **684** and **686**, sliding rotor **668** out through bearing **666**.

Lower seal pad **688** is disposed partially in cavity **658**, with seal **690** located in groove **692**, sealingly engaging groove **692** and wall **658***a*. Lower seal pad **688** includes surface **694** which, when assembled, contacts peripheral surface **672** of rotor **668**, forming a seal therewith, as described below. Bracket **696** is attached to block **652** by fasteners (not shown), and has portion **696***a* which overlies the upper surface of lower seal **688** so as to retain lower seal **688** to block **652**. As used herein, "pad" is not used as limiting: "Seal pad" refers to any component which forms a seal.

Upper seal pad **698** includes surface **200** which, when assembled, contacts peripheral surface **672** of rotor **668**. Upper seal pad **698** and lower seal pad **688** may be made of any suitable material, such as a UHMW material. The ends of surfaces **694** and **200** may be chamfered to allow easier insertion of rotor **668**.

As seen in FIG. **38**, lower pad seal **688** is disposed in cavity **658**, with seal **690** engaging wall **658***a*, and upper pad seal **698** overlying but not engaging lower pad seal **688**, surface **200** engaging rotor **668**. Surface **694** includes two openings **204** which are in fluid communication with inlet **654** through upstream chamber **208**, and two openings **206** which are in fluid communication with outlet **656** through downstream chamber **210**. It is noted that although two openings **204** and two openings **206** are present in the illustrated embodiment, the number of openings **204** and openings **206** may vary, depending on the design of feeder assembly **512**. For example, a single opening may be used for each. Additionally, more than two openings may be used for each.

Feeder assembly **512** has a transport gas flowpath from inlet **654** to outlet **656**. In the depicted embodiment, passageways **212** and **214** are formed in feeder block **652**. Lower seal pad **688** includes recess **216**, which is aligned with inlet **654** and together with passageway **212**, places upstream chamber **208** in fluid communication with inlet **654**. Lower seal pad **688** also includes recess **218**, which is aligned with outlet **656** and together with passageway **214**, places downstream chamber **210** in fluid communication with outlet **656**.

Upstream chamber **208** is separated from downstream chamber **210** by wall **216** which extends transversely across lower seal pad **688**. Lower surface **216***a* of wall **216** seals against bottom **658***b* of cavity **658**, keeping upstream chamber **208** separate from downstream chamber **210**. Wall **218** is disposed perpendicular to wall **216**, with lower surface **218***a* engaging bottom **658***b*.

As illustrated, in the depicted embodiment, inlet **654** is in fluid communication with outlet **656** substantially only through individual pockets **674** as they are cyclically disposed by rotation of rotor **668** between a first position at which an individual pocket first spans openings **204** and **206** and a second position at which the individual pocket last spans openings **204** and **206**. This configuration directs substantially all of the transport gas entering inlet **654** to pass through pockets **674**, which pushes the blast media out of pockets **674**, to become entrained in the transport gas flow. Turbulent flow occurs in downstream chamber **210**, promoting mixing of media with the transport gas. Such mixing of the media entrains the media in the transport gas, minimizing impacts between the media and the feeder components downstream of the pockets. The significant flow of the transport gas through each pocket **674** acts to effectively clean all media from each pocket **674**.

It is noted that there is a gap above top **216***b* of wall **216** and top **218***b* of wall **218** and peripheral surface **672** of rotor **668**. Some transport gas flows across tops **216***b* and **218***b* from upstream chamber **208** to downstream chamber **210**.

Particles generated by action of the working edges across a block or a plurality of pellets disposed in supply bin **581**, or particles passed through openings **592**, travel directly through collector chamber **562** and internal passageway **568** into feeder assembly **512**. The relative rates of rotatable carriage **540** and rotor **668** is set such that the displaced volumetric rate of pockets **574** is greater than the particle capacity of rotatable carrier **540** and associated parts at maximum speed. Thus, such particles reach feeder assembly **512** without being held or stored for any appreciable time period.

Alternative Slide Embodiment

Referring to FIGS. **39-43**, a plurality of movable inserts **702**, also referred to herein as slides **702**, are disposed in respective recessed openings **704** which are similar to openings **604** described above. Edges **716** of recessed openings **704** define a fixed boundary of openings **592**, with movable edges **706** of slides **702** defining the other boundary. Each slide **702** has a generally T shaped configuration that is similar to slide **602** described above.

FIGS. **39-40** show insert **702** disposed in opening **704** in an open position, such that opening **592** is at a maximum size. As shown in FIG. **40**, end **709** of central portion **708** is disposed above surface **715** defining recessed opening **704** and terminating at edge **717** that is spaced apart from edge **716**. FIG. **41** shows lever **726** rotated in the direction of arrow (A) to a position from which it is possible to move insert **702** in the direction of arrow (B). As further described below, lever **726** is then rotated in the direction of arrow (C) to positively locate insert **702** with opening **604** in a closed position, as shown in FIGS. **42-43**. In the closed position, opening **592** is closed and at its minimum size. Further, in the closed position, a portion of surface **715** is exposed as shown as surface **715***a* in FIG. **43**.

As shown in FIGS. **40**, **41**, and **43**, insert **702** includes pin **730** that projects from an undersurface of insert **702** and is configured to be received in one of two openings **732** or **734** in surface **715** of recessed opening **704**. When insert **702** is in an open position as shown in FIG. **40**, a sufficient portion of pin **730** is disposed within first opening **732** so as to provide positive locating of insert **702** within opening **704** sufficient to resist movement. To adjust insert **702**, as shown in FIG. **41**, lever **726** is rotated in the direction of arrow (A), allowing slide **702** to be moved away from surface **715** such that pin **730** is no longer disposed in first opening **732**. Insert **702** may then be moved in the direction of arrow (B) to a location at which pin **730** aligns with second opening **734**, and moved toward surface **715** causing pin **730** to be disposed within second opening **734**. Lever **726** is rotated in the direction of arrow (C) to hold slide **702** adjacent or at least sufficiently proximal surface **715** such that at least a portion of pin **730** remains disposed in second opening **734** so as to positively locate insert **702** within opening **704** sufficient to resist movement of slide **702** from the closed position as shown in FIG. **43**. Alternately, pin **730** and first and second openings **732**, **734**, may be replaced by a resilient detent configuration, such as with a spring and ball detent carried by slide **702** engaging shallow openings in surface **715** in place of first and second openings **732**, **734**, sufficiently strong to retain slide **702** in the desired location. Although only open and closed positions are illustrated, it is within the scope of the present disclosure to provide one or more additional positive locating positions for slide **702** intermediate the full open and full closed positions.

The foregoing description of one or more embodiments of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Obvious modifications or variations are possible in light of the above teachings. The embodiment was chosen and described in order to best illustrate the principles of the invention and its practical application to thereby enable one of ordinary skill in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. Although only a limited number of embodiments of the invention is explained in detail, it is to be understood that the invention is not limited in its scope to the details of construction and arrangement of components set forth in the preceding description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced or carried out in various ways. Also, in describing the preferred embodiment, specific terminology was used for the sake of clarity. It is to be understood that each specific term includes all technical equivalents which operate in a similar manner to accomplish a similar purpose. It is intended that the scope of the invention be defined by the claims submitted herewith.

Another embodiment of the present invention is described in U.S. Provisional Patent Application Ser. No. 61/594,347, filed on Feb. 2, 2012, titled APPARATUS AND METHOD FOR HIGH FLOW PARTICLE BLASTING WITHOUT PARTICLE STORAGE, which is incorporated herein by reference and which is set forth Appendix A of this application.

The foregoing description has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Obvious modifications or variations are possible in light of the above teachings. The embodiment was chosen and described in order to illustrate the principles of the invention and its application to thereby enable one of ordinary skill in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. Although only a limited number of embodiments of the invention is explained in detail, it is to be understood that the invention is not limited in its scope to the details of construction and arrangement of components set forth in the preceding description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced or carried out in various ways. Also, specific terminology was used herein for the sake of clarity. It is to be understood that each specific term includes all technical equivalents which operate in a similar manner to accomplish a similar purpose. It is intended that the scope of the invention be defined by the claims submitted herewith.

We claim:

1. A method of utilizing a rotatable carrier to generate particles of solid carbon dioxide for introduction into a transport gas flow system, said method comprising the steps of:

a. providing a particle generator comprising a first side, a second side, and a plurality of first and second openings, each of said first openings having a respective size which is selectively settable at one of a first size and a second size;

b. selectively setting the respective size of at least one of the plurality of first openings at the first size if particles are to be generated from discrete particles and at the second size if particles are to be generated from a block;

c. urging one of a block or discrete particles of solid carbon dioxide against the first side of the particle generator;

d. rotating the particle generator; and

e. generating particles from the second side of the particle generator.

2. The method of claim **1**, wherein the step of selectively setting the respective size of at least one of the plurality of first openings comprises the step of positioning a respective insert at a respective first location so as to set the respective size at the first size.

3. The method of clam **2**, wherein the step of positioning a respective insert at a respective first location comprises the step of positively locating the respective insert at the respective first location.

4. The method of claim **3**, wherein the step of positively locating the respective insert comprises the step of engaging the respective insert with a pin.

5. The method of claim **1**, wherein the step of selectively setting the respective size of at least one of the plurality of first openings comprises the step of positioning a respective insert at a respective second location at which the respective insert closes the at least one of the plurality of first openings.

6. The method of claim **5**, wherein the step of positioning a respective insert at a respective second location comprises the step of positively locating the respective insert at the respective second location.

7. The method of claim **6**, wherein the step of positively locating the respective insert comprises the step of engaging the respective insert with a pin.

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